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Sport Fishing: A Comparison of Three Indirect Methods for Estimating Benefits

Technical Editors

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Abstract

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Three market-based methods for estimating values of sport fishing were compared by using a common data base. The three approaches were the travel-cost method, the hedonic travel-cost method, and the household-production method. A theoretical comparison of the resulting values showed that the results were not fully comparable in several ways. The comparison of empirical results showed differences in values not easily accounted for on theoretical grounds. The data base was not designed to provide data for all three methods, and some of the resulting models explain only a small proportion of the variation.

Keywords: Recreational value, fishing, models.

Summary

We compared and critically evaluated three different market-based methods for estimating values of sport-fishing experiences. Values of particular interest were the average and marginal values of sport-caught salmon and steelhead in Oregon. Previous studies focused on average values of the fishing experience rather than on values of the fish catch. Values of fish may be useful in evaluating the efforts to protect and enhance fisheries.

The three methods we considered were the travel cost (both zonal-average and individual-observation versions), the hedonic travel cost, and the household production. All three methods are derived from a constrained utility-maximization problem, but they make different assumptions about an angler's process in making decisions, particularly about the role of quality characteristics of a site (such as the fishing success rate).

Empirical results are presented from four independent studies, each applying one method to data collected in a 1977 mail survey of Oregon anglers. Because the questionnaire was designed with the travel-cost method in mind, some difficulties were encountered in using the data to develop the other models. This, combined with not all the approaches being used to derive quite the same set of values, made a comparison of empirical results difficult. The household-production method was used only to estimate values for steelhead fishing, and the hedonic travel-cost method was used only to derive values for salmon fishing.

Results from the travel-cost model could be compared to those from the other two methods because the travel-cost method was used for both the salmon and the steelhead data. The value of a steelhead-fishing experience was greater in the travel-cost method than in the household-production method ($27 and $21, respectively) as was the value of a sport-caught steelhead ($155 and $84, respectively). The hedonic travel-cost method provided a higher estimate of the value of a salmon-fishing experience (ocean and river fishing combined) than did the travel-cost method ($177 and $141, respectively). Estimates of the value of sport-caught salmon were much closer—$254 and $248 from the hedonic travel-cost method and the travel-cost method, respectively.

We expected the results from the three models to differ, but not all the differences were easily accounted for by theory. This report outlines the theoretical conditions under which results should be similar, but value estimates in the models can also be affected by model specification, functional form, and valuation procedures.

One major outcome of this work was learning that a significant amount of preplanning in questionnaire design is necessary if a single data base will be used to estimate values by more than one method. In the early stages of any research effort to estimate recreational benefits, the scientist must determine and plan for theoretical assumptions, econometric procedures, and policy considerations. All three will affect the choice of approach and model specification, and these, in turn, will affect the types of data and experimental designs needed to produce the best results. Our primary intent was to provide researchers and potential users of value estimates with information to help them choose the best methods for their work.

Contents

Chapter 1: Introduction

Darrell L. Hueth, Elizabeth J. Strong, and William G. Brown[1]

Forest managers are concerned not only with timber harvest but also with alternative uses of forests, such as preservation of wildlife in wilderness areas, protection of streams, reforestation, and recreation. Rational management decisions can be made if the prices of all alternative uses are available. The value of timber is the most easily calculated because timber eventually passes through the market system. Values for recreational activities, such as fishing, hunting, and river rafting, are much more difficult to estimate. We examined three ways to estimate values of one recreational activity in Oregon—sport fishing.

Values of particular interest are the average and marginal values of sport-caught steelhead and salmon. Most earlier studies (for example, Brown and others 1964, Wennergren 1967) focus on values of recreational experiences and recreational sites and not on values of fish caught.[2] Estimates of marginal values associated with marginal changes in fish catch have therefore not been available.

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[2] An exception to this statement is an innovative, recent study by Samples and Bishop (1985) in which they estimate the value of differences in success rates of anglers at various sites by relating estimated consumer surplus to success rates at the various sites. We essentially followed the approach of Samples and Bishop except that we related the value of differences in fish catch, based on differences in estimated consumer surplus, to fish catch from river to river.

Some crude average values can be obtained from travel-cost studies by dividing the estimated total consumer surplus by the total sport harvest of fish or game, but the validity of using such values to make marginal decisions affecting fish and game abundance and harvest has been justifiably questioned. If sport-fishing effort can be regarded as independent of fish catch, then the average values are important for knowing how marginal changes in fish abundance affect the value of sport fishing.

If no knowledge of marginal fish values is available, an efficient allocation of public funds and natural resources is unlikely. For example, if the value of salmon and steelhead sport fishing in the Pacific Northwest is unrelated to fish catch, then there is no economic justification for public expenditures on fish hatcheries and stream improvement to enhance, or to even maintain, salmon and steelhead runs, at least so far as angler benefits are concerned. On the other hand, if a strong positive relation between fish catch and the benefits from salmon and steelhead sport fishing exists, then use of public resources to protect or enhance the runs can be justified. In either case, there are important noneconomic reasons to maintain salmon and steelhead runs.

Forest Management and Sport-Fishing Benefits

The value of forest streams in sport fishing can be both directly and indirectly influenced by forest land-management practices. Direct effects result when forest land-use decisions influence the scenic attributes of the fishing site that, in turn, influence the attractiveness of a site for sport fishing. Some environmental quality changes not perceived by anglers still have indirect effects on angler demand; for example, indirect effects result when changes in water quality caused by forest-management activities influence the abundance or catchability of fish in a stream. These are called indirect effects because, unlike the scenic attributes of a site, they may not cause anglers to derive direct pleasure out of a productive habitat or clear water but to benefit indirectly by catching more fish.

Figure 1 illustrates a system that relates forest management to benefits of sport fishing. The arrows indicate the directions of causation; for example, the upper part of the diagram shows that forest-management practices (that is, logging or road construction) near a stream might affect the attractiveness of fishing sites to anglers. Reduced scenic quality of a site may directly reduce use of the site, as measured by the number of fishing trips taken. Additional logging roads could result in increased use of forest streams, however, by making remote sites more accessible, particularly if anglers do not make scenery a high priority when choosing a site.

The left side of figure 1 shows that logging and road construction can also reduce water quality in forest streams. Such changes might lead to immediate reductions in the catchability of fish, the stocks of young and adult fish, and the productivity of fish habitats. Changes in fish catchability and adult fish stocks immediately affect the number of fish an angler can catch with the same amount of effort; changes in smolt survival and productivity of the habitat cause delayed effects on the productivity of anglers in catching fish.

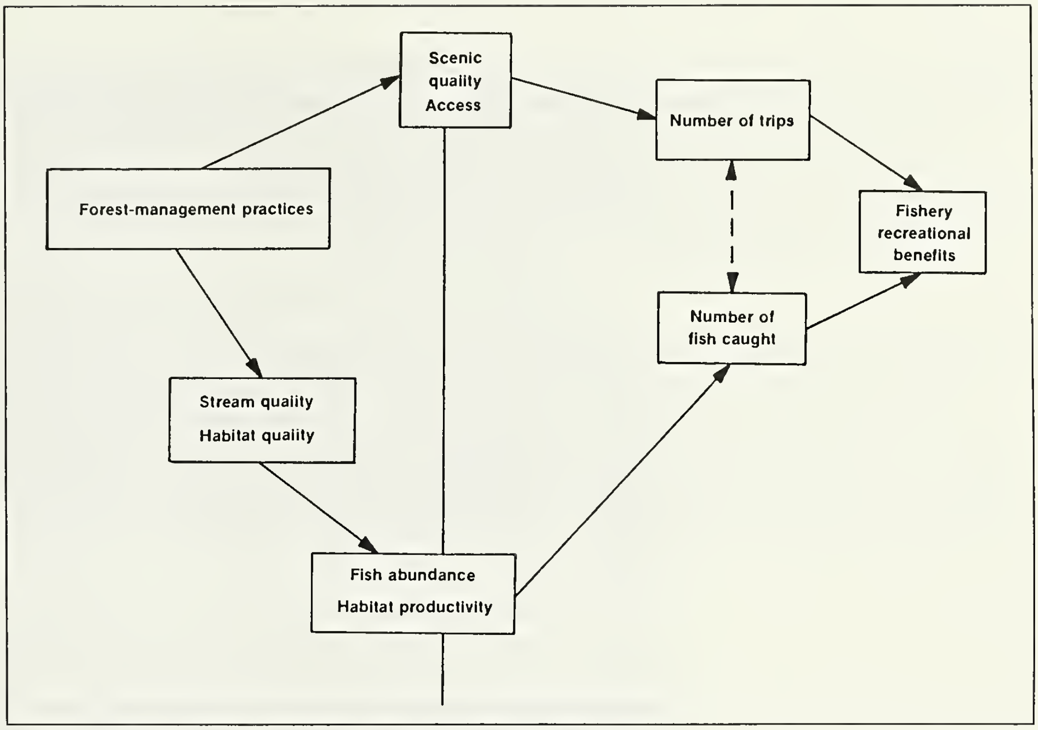

Figure 1—A conceptual model of the direct and indirect effects of forest-management policies on recreational benefits.

Finally, changes in the fishing success rate at a site affect the value of that site resource as a sport fishery. This value is measured, by nonmarket valuation techniques, as the benefits anglers receive from visiting the site. In some nonmarket valuation models, the number of fish caught is viewed as directly generating recreational benefits; in other models, effects of fish catch are viewed as moving in the direction of the dashed arrow (see fig. 1) and indirectly affecting recreational benefits by changing the number of trips taken.

Forest resource managers have trouble developing and empirically testing a model such as that suggested in figure 1. Biologists, hydrologists, and fishery and forest resource managers want to work with economists to determine economic values for fish populations, but only limited progress has been made. So far, the first part of the system (to the left of the vertical solid line in fig. 1), which relates logging activities to stream quality, has seen the most research (Brown 1976, Chamberlain 1982). A notable research effort in Oregon identified changes in sediment concentration, dissolved oxygen concentration, water temperature, and streamflow as some of the direct consequences of timber harvesting and road construction (Moring and Lantz 1975). Because these attributes are important to anadromous fish habitat, logging-induced quality changes are believed to influence anadromous fish production. Although well-documented evidence of logging-induced changes in the physical quality of Pacific coast streams exists, the complexity of river and estuarine ecosystems has slowed research on the environmental impacts of logging on productivity of anadromous fisheries. Efforts to develop models that estimate logging-stream quality relationships have also been hampered by the complexity of forest ecosystems and by the difficulties in extrapolating the observed relationships from one river system to another in a different geographic area.

As we said, the relationship between water-quality parameters and angler benefits is indirect; that is, they are mainly related through the effects of water-quality changes on fish abundance and, hence, the number of fish caught. To make the connection between forest-management practices and the benefits of sport fishing, the link must be established between water quality and fish abundance. At present, little information is available on that link.

Most valuation models for recreation have begun with data on items to the right of the vertical solid line (see fig. 1); that is, they have been designed to measure the relationship between fishing activities and the value of fishery resources. We extended the analysis to measure the relationship between fish catch and the value of fishery resources to estimate the value of a sport-caught fish. In addition, the household-production method presented in this paper is, perhaps, the first attempt to establish an empirical relationship between habitat quality and fish catch, which can then be used to estimate the effects of changes in water quality on recreational values.

Two general approaches are used to measure recreational benefits of fishing. The first, contingent valuation, uses direct interviewing to elicit values from users and potential users of recreational sites. The second, a market-based approach, uses actual expenditures on marketed goods and posits relationships between these goods and recreational activities to estimate recreational benefits.

Project Objectives

The objective of our research was to compare and evaluate three market-based methods for estimating values of recreational fishing by using one common data base. Data obtained from a 1977 survey of Oregon anglers, which is described below, was used to estimate values by using the travel-cost method (TC), the hedonic travel-cost method (HTC), and the household-production method (HP). The data base was used to estimate both the traditional zonal-average travel-cost and the individual-observation travel-cost models, both adjusted and unadjusted.

A second objective of this research was to provide estimates of average and, where possible, marginal values of salmon and steelhead. These values are important in forest-management decisions and also in other settings, particularly in the evaluation of projects to enhance fish production in a river system.

Description of the Data

A sample of 9,000 anglers was drawn from purchasers of Oregon angling licenses during 1977. This sample was about 1.5 percent of the total licenses sold, including in-State and out-of-State licenses of all categories. A questionnaire was used to obtain quarterly data from the anglers about their fishing-related expenditures and fishing activities. Questionnaires were mailed at the end of each quarter during 1977. For the first quarter, January 1 through March 31, 1,200 questionnaires were sent; 2,700 were sent out for the second quarter; 3,600 for the third quarter; and 1,500 for the fourth. We anticipated we would receive more information from the survey by concentrating the sampling in the most active fishing seasons—spring and summer.

An extensive followup by mail and telephone resulted in a return of 55.6 percent. Besides nonrespondents being reminded by telephone to complete and return the questionnaires, any respondent whose questionnaire was incomplete or suspected of being erroneous in some respect was also telephoned. Although this procedure was costly and time consuming, the quality of the information from the survey was greatly improved by the telephone followup. More detailed information about the survey design is reported by Sorhus (1980) and Sorhus and others (1981). A copy of the questionnaire is in the appendix to this chapter.

Organization of This Paper

Chapter 2 presents a critique of the methods based on the theoretical foundations of angler's choices, statistical and econometric considerations, data requirements, and policy implications (that is, what questions each method is best able to answer). Chapters 3, 4, 6, and 7 present the results of using each method to estimate recreational benefits. Chapter 5 provides additional comments on the strengths and weaknesses of zonal-average, individual-observation, and adjusted individual-observation formulations of the travel-cost method. Chapter 8 compares, insofar as possible, the empirical results from using the three basic techniques.

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Appendix

OREGON FISHING ACTIVITIES QUESTIONNAIRE

1. Did you, yourself, go fishing *in Oregon* any time during the last 3 months (January-March 1977), or not?

   ____ Yes, fished. (Go to Question 2) ____ No, did not fish. (Go to Question 5)

2. How many times did you go fishing from January through March 1977? ____ Number.

3. Of these trips, how many were intended primarily as fishing trips, as contrasted to trips taken mainly for other reasons (but where some fishing was done)? ____ Number.

4. Of all your fishing trips, how many were primarily for steelhead? ____ Number.

   How many were primarily for salmon fishing? ____ Number.
   How many for resident trout? ____ Number.
   How many for any other species? (Please specify ______) ______ Number.

5. What type of fishing license(s) did you, yourself, purchase for 1977? (Please check all that apply.)

   - ☐ Resident Combination
   - ☐ Resident Combination with bow
   - ☐ Resident Angler
   - ☐ Juvenile Angler
   - ☐ Nonresident Angler
   - ☐ 10-day Angler
   - ☐ 1-day Angler
   - ☐ 2-day Angler
   - ☐ 3-day Angler
   - ☐ Pioneer Angler
   - ☐ Disabled Vet Angler
   - ☐ Senior Citizen Angler

6. In addition, did you purchase a salmon-steedhead tag? ____ Yes ____ No

7. What is *your* approximate age?

   - ☐ Under 21
   - ☐ 21-29
   - ☐ 30-39
   - ☐ 40-49
   - ☐ 50-59
   - ☐ 60-69
   - ☐ 70 years or over

8. How many people, including yourself, are in your household and living at home at the present time? ____ Number.

9. Please indicate the average number of hours, if any, you were working for pay during the last three months. Please check if you are retired or are a student.

   ____ Number of hours worked per week.
   ____ Retired.
   ____ Student.

10. Which of the following categories most closely corresponds to the combined yearly income, before taxes, for *all* members of your household for 1976?

    - ☐ Under $3,000
    - ☐ $3,000-$ 4,999
    - ☐ $ 5,000-$ 7,999
    - ☐ $ 8,000-$11,999
    - ☐ $12,000-$14,999
    - ☐ $15,000-$17,999
    - ☐ $18,000-$ 24,999
    - ☐ $25,000-$ 34,999
    - ☐ $35,000-$ 49,999
    - ☐ $50,000-$100,000
    - ☐ Over $100,000

(PLEASE TURN TO PAGE 2 IF YOU FISHED IN JANUARY-MARCH 1977:
PLEASE TURN TO PAGE 4 IF YOU DID NOT)

PLEASE ANSWER THE FOLLOWING QUESTIONS (11-21) ABOUT YOUR LAST 3 *OREG(*

IF YOU TOOK LESS THAN 3 TRIPS, PLEASE FILL IN ONLY THE QUEST

11. Write name of river, stream, or name of lake (or ocean) where this fishing trip took place ....

12. In what county was this port, river, lake, or stream where you fished? (See map on back of introductory letter) ....

13. How many miles did you travel, one way, on your fishing trip? ....

14. Did you make this trip in an automobile or a pickup without a camper?
Circle YES or NO ....

15. Did you make this trip in a motor home, auto with camper, or a pickup camper?
Circle YES or NO ....

16. How many hours (or days) did you spend at your destination? ....

17. When you were developing your plans for this trip, what was the shortest length of time you would have considered staying at your destination, in hours (or days)? ....

18. How many *hours* did you actually fish? (If for more than one species, divide the time among species):
STEELHEAD ....
SALMON ....
RESIDENT TROUT ....
SEA-RUN CUTTHROAT ....
WARM WATER GAME FISH ....
OTHER ....

19. How many fish of each species did you, yourself, catch?
STEELHEAD ....
SALMON ....
RESIDENT TROUT ....
SEA-RUN CUTTHROAT ....
WARM WATER GAME FISH ....
OTHER ....

20. How many people went with you on this trip? ....

21. Approximately how much did you *and your group* spend for the following items? (Just your best estimate)
(a) Food, drink (including liquor), bought in restaurants, bars, or taverns, while traveling to and from your destination ....
(b) Food and drink bought in restaurants, bars, and taverns while at your destination ....
(c) Total amount spent for camping fees, lodging in motels and hotels, while traveling to and from your destination ....
(d) Amount spent for camping fees and lodging while at your destination ....
(e) Guide service, bait, and lures ....
(f) Rental of fishing tackle, equipment, boat, and/or motor ....
(g) Boat launching fees ....
(h) Gallons of gas used in your boat (do not include rental boats and motors) ....
(i) Other *rental* items (Specify) ____________ ....
____________ ....
(j) Miscellaneous expenses (Specify) ____________ ....
____________ ....

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ON FISHING TRIPS DURING THE PERIOD JANUARY THROUGH MARCH 1977.
IONS REFERRING TO THE NUMBER OF TRIPS YOU TOOK.

TRIP 1		TRIP 2		TRIP 3	
________		________		________	
________		________		________	
________		________		________	
YES ____	____ NO	YES ____	____ NO	YES ____	____ NO
YES ____	____ NO	YES ____	____ NO	YES ____	____ NO
____ hours	____ days	____ hours	____ days	____ hours	____ days
____ hours	____ days	____ hours	____ days	____ hours	____ days
$ ________		$ ________		$ ________	
$ ________		$ ________		$ ________	
$ ________		$ ________		$ ________	
$ ________		$ ________		$ ________	
$ ________		$ ________		$ ________	
$ ________		$ ________		$ ________	
$ ________		$ ________		$ ________	
________ gals.		________ gals.		________ gals.	
$ ________		$ ________		$ ________	
$ ________		$ ________		$ ________	
$ ________		$ ________		$ ________	
$ ________		$ ________		$ ________	

PLEASE GO ON TO NEXT PAGE

22. Listed below are items often used by fishermen. Please record your expenditures for equipment, regardless of when purchased, that you still use in your Oregon fishing activities. To see how to complete percents for the last two columns, please refer to the following example:

EXAMPLE: Assume you purchased a boat, and use it a total of 100 hours per year. Of this 100 hours, 50 hours were used for all angling, of which 25 hours were for salmon and steelhead angling. In this case, 50% should be allocated to *all* angling, and 25% should be allocated to salmon and steelhead fishing.

Item	Purchase price	Year(s) in which purchased	State in which purchase was made	Replacement cost today	Percent of time item is used for all fishing	Percent of time item is used for salmon and steelhead fishing
	dollars			*dollars*	%	%
Tackle:						
Rod(s)	$			$	100	
	$			$	100	
	$			$	100	
Reel(s)	$			$	100	
	$			$	100	
	$			$	100	
Creel(s)	$			$	100	
Tackle box(es)	$			$	100	
Landing net(s)	$			$	100	
Any other tackle	$			$	100	
Boating equipment:						
Boat(s)	$			$		
Boat trailer(s)	$			$		
Outboard motor(s)	$			$		
Any other	$			$		
Special clothing:						
Waders, Hipboots	$			$		
Fishing vest(s)	$			$		
Coat(s)	$			$		
Rainwear	$			$		
Any other	$			$		
Camping equipment:						
Tent(s)	$			$		
House trailer	$			$		
Camper(s)	$			$		
Pickup truck(s)	$			$		
Sleeping bags	$			$		
Lantern(s)	$			$		
Stove(s)	$			$		
Any other	$			$		
Other equipment expenditures not listed above; (specify):						
________	$			$		
________	$			$		

Is there anything else you would like to say about fishing in Oregon? Please return questionnaire and any comments you would like to make in envelope provided.

THANK YOU FOR YOUR COOPERATION.

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Chapter 2: A Critical Review of Three Recreation-Valuation Methods

Darrell L. Hueth and Elizabeth J. Strong[1]

Introduction

We compared three recreation-valuation models—the travel-cost (TC), the hedonic travel-cost (HTC), and the household-production (HP)—by their theoretical basis, econometric procedures, and policy considerations. The major focus was on how these models can be used to evaluate the benefits to recreationists of changes in the quality of recreation sites. Bockstael and McConnell's (1981) formulation of the HP model for sport fishing is used. Other variants, such as the HP model used by Smith and others (1983), are mentioned only briefly.

The first section of this chapter is a discussion of the conceptual framework each model is derived from. In that section, the assumptions underlying each model are outlined, and the procedures for measuring benefits are described. The second section provides a comparison of the three models based on data requirements, statistical problems, and estimation techniques. The third section evaluates the three models by the types of quality variables that can be included in each, which suggests what types of policy questions each model is capable of handling. The final section briefly summarizes the major points.

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Theoretical Basis

The three recreation-valuation methods described here are classified as indirect, market-based approaches. Underlying each method is a behavioral model describing individuals' decisions from which nonmarket values can be inferred. The behavioral models are based on a common hypothesis of constrained utility maximization, where the utility function is defined on nonmarket goods, and the budget constraint is usually constructed by defining an implicit price for each nonmarket good. These implicit prices are derived from hypothesized relationships between each nonmarket good and some set of market goods. For example, the implicit price of a visit to a recreational site is determined primarily by the relationship between this commodity and the market transportation goods (such as gas, food, and lodging) purchased by anglers while traveling to and from the site. Implicit prices can also be determined for commodities describing the quality of a recreational experience.

Conceptually, the three recreation-valuation methods differ mainly in the relationships posited between recreational commodities and market goods. Also, the methods assume different levels of influence for the recreationist in determining implicit prices and in determining the quality of a recreational experience. The recreationist is given the least flexibility in the basic single-site TC method and the most flexibility in the HP method. In other words, the TC method makes stronger assumptions about the recreationist's process for making decisions than does the HTC method, and the HTC method makes stronger assumptions than does the HP method.

The Travel-Cost Method

The TC method views the number of visits to a given site as the only recreation-related choice variable in the model. The underlying utility function is written as $U = U(v,z,y)$, where v is the number of visits to a given site, z is the quality characteristics of the site, and y represents all the other commodities in the recreationist's choice set. This method assumes that transportation expenditures (and sometimes travel time) are perfect complements to the recreational experience and, thus, can serve as a proxy for the nonexistent price of a visit.[2]

If it is assumed that transportation costs are constant across visits, then a demand equation for visits to a single site can be constructed by specifying the number of visits as a function of this fixed price and other demand determinants, including income and z. The demand equation for visits is theoretically found by maximizing the utility function $U = U(v,z,y)$, subject to the budget constraint $M = p_v(v) + y$, where M is total income and p_v is the fixed price of a visit. (The price of y is assumed to be unity.) In most applications of the TC method, however, the demand equation for visits is not related to a specific utility-maximization problem. The estimated TC demand equation is normally used to determine the value of a recreational experience based on the consumer surplus associated with changes in the travel-cost variable p_v.

[2] This is the traditional explanation for the TC method. In recent literature, the TC model has been derived from two different HP models. Bockstael and McConnell (1981), for example, show that the TC model is a special case of their more general HP model. Smith and others (1983) show that the TC model can be derived from a different formulation of the HP model. In their model, the number of visits to each site is treated as a nonmarket input in the production of recreational service flows. The TC demand equation is interpreted as the reduced form of the derived input demand equation for visits.

In a TC model, the quality of a recreational experience is assumed to be completely outside the control of the recreationist. Preferences for various quality characteristics are revealed only indirectly through the recreationist's decisions on which sites to visit and how many times to visit a particular site. Quality factors influencing the choice of site or participation rate at a given site may be included directly in TC demand equations. The benefits of marginal changes in quality can then be evaluated by calculating changes in consumer surplus associated with quality-induced shifts in the demand curve, but only when the quality factor is weakly complementary to the number of visits.[3] When the weak complementary condition does not hold, the benefits of quality changes can be determined only if the form of the underlying indirect utility function or its equivalent—the expenditure function—were known. As noted earlier, the demand equation has not typically been derived from a specified utility function in empirical applications of the TC method.

The Hedonic Travel-Cost Method

Like the TC method, the HTC method assumes a fixed travel cost per trip to any given site. This method assumes the recreationist has more flexibility than does the TC method, however, by explicitly accounting for the direct influence that recreationists have over the quality of recreational experiences, which comes from choosing sites with different attributes. In fact, the HTC method is based on the assumption that the only reason a recreationist would travel to a more distant site would be to have a higher quality recreational experience. This assumption implies that additional travel costs incurred on a trip to a more distant site can be used to represent the implicit value of the additional quality characteristics.

In the HTC method, the implicit price of each quality characteristic is derived from an estimated hedonic price equation, which is written as $p_v = p_v(z_i)$, where p_v is the price per visit and z_i represents quality characteristics of a recreational experience at a given site. The partial derivative of the hedonic price equation with respect to any z_i yields the marginal hedonic price (or the implicit price) for that characteristic.

A hedonic method can be used to determine implicit prices of the quality characteristics of any type of goods, as long as different varieties of the goods are available and these varieties differ only in their prices and quality characteristics. The hedonic price function relates the market price of any variety of the goods to the characteristics possessed by that variety.

In the HTC method, each class of goods is made up of the recreational trips taken by individuals from a given zone of origin, and the different varieties correspond to the different sites providing services to that zone. These sites differ in distance from the zone (and, hence, the travel cost per visit) and in quality of the characteristics offered. The supply of a quality characteristic at any given site is assumed to be outside the control of the recreationist.

The decision framework for the recreationist is designed as if the decisions on site choice and participation rate were made in two stages. In the first stage, the recreationist selects a bundle of characteristics and in the second stage decides how many trips to take to a site offering that bundle. If the recreationist visits only one

[3] A quality variable, z, is weakly complementary to v iff $\partial U / \partial z \mid_{v=0} = 0$.

site, the utility function is $U = U(v,z_i,...,z_m,y)$.[4] The utility function is maximized subject to the budget constraint, $M = p_v(z) + y$, to derive the ordinary demand equations for v and the z_i's. The derived demand equations for the m + 1 choice variables are in the general case written as:

$$z_i = g_i(p_1(z),...,p_m(z),p_v(z),M),$$

where i = 1,...,m; and

$$v = g_v(p_1(z),...,p_m(z),p_v(z),M),$$

where $p_i(z) = \partial p_v(z) / \partial z_i$.

Recreationists treat these implicit prices as parameters in their decisions. Even though these prices are not necessarily constant, they are considered to be exogenously determined in this framework because consumers are unable to influence the hedonic price function; that is, the function $p_v(z)$ is the same for all consumers and is independent of v. This function and the corresponding marginal price functions are apparently regarded as being determined by production costs in the HTC framework (Rosen 1974).[5]

Rosen (1974) argues that observed implicit prices of characteristics merely reflect equilibrium conditions and reveal little about the underlying structures of production technologies and consumer preferences. Rosen (1974) shows that simultaneously estimating supply and demand equations for characteristics, when the previously estimated hedonic price equation is given, is a feasible econometric procedure for identifying the underlying structures of producer technologies and consumer preferences. He further states that where production conditions are identical for firms producing different varieties of the same goods, the observed implicit price functions can be regarded as supply functions for the characteristics.

In the HTC model, if no technological differences exist among sites that provide services to a given zone, then the implicit price functions may be referred to as supply functions for the quality characteristics. The sites can be thought of as representing different firms, each producing a different variety of the recreational experience. But this concept of individual firms is misleading, because the HTC method assumes that the only way a different quantity of a characteristic could be rendered to a recreationist is if that recreationist visits a different site; that is, each site is assumed to be unable to alter its bundle of characteristics. It is as if the sites do not operate

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[4] Muellbauer (1974) notes that the choice of only one site "...is imposed as an extraneous assumption rather than as the outcome of the optimizing model" (p. 992). A multiple-site TC model will allow the recreationist to visit any number of sites with different quality characteristics. Although quality characteristics are not treated as endogenous choice variables in such a model (as they are in the HTC model), the recreationist can indirectly influence the quality of recreational experiences by visiting various sites. Because the multiple-site TC model does not limit the recreationist to a single site, it is actually less restrictive than the HTC model.

[5] Rosen's viewpoint runs contrary to other theories, such as the theory of household production, that have also been used to justify the hedonic technique. These other theories are not consistent with Brown and Mendelsohn's (1984) formulation of the HTC model, as is Rosen's interpretation. See Muellbauer (1974) and Deaton and Muellbauer (1980) for comparisons of the different theoretical approaches.

independently of one another and do not compete with one another for visitors but are instead controlled by a single, hypothetical owner, and the technology for this owner is described by a single hedonic price function. It follows from this assumption that the HTC method implicitly assumes that production conditions are identical across sites providing services to a given zone. The implicit price equations can, therefore, be viewed as identifying characteristic supply curves for the single hypothetical producer.

With the HTC technique, the structure of consumer preferences is identified by fitting demand equations for characteristics. To trace out demand equations for characteristics, a sufficiently large number of supply curves for each characteristic are needed. Because each hedonic price function describes the production technology for a different zone of origin, the supply curves for characteristics will differ across zones. (A given site will have more than one supply curve for each characteristic if that site supplies services to more than one zone.) Thus, the characteristic supply curves across zones are used to identify characteristic demand equations for a representative zone.

The fitted supply and demand equations for characteristics can be used to obtain estimates of the value of a recreational experience and benefits to recreationists from changes in implicit prices. Because the HTC method assumes that characteristic supplies are exogenously determined, estimates of the benefits to recreationists of marginal changes in the supply of characteristics can also be obtained. This is equivalent to evaluating the benefits of changes in implicit characteristic prices because shifts in supply result in changes in equilibrium prices. The assumption must be made that these changes automatically lead to equivalent changes in the demand for characteristics in order to evaluate the benefits of changes in characteristic supplies.

Either the demand equation for characteristics or the demand equation for visits can be used to obtain an estimate of the value of a recreational experience. In the visits market, estimates of recreational benefits are calculated in the same way as they are in the TC demand model, discussed above; that is, the total area under the demand curve for visits and above the horizontal price line gives an estimate of total benefits for the recreationist. This measure of total benefits is divided by the number of visits to obtain an estimate of the average value of a recreational experience.

The above procedure is equivalent to estimating the benefits of sequentially increasing implicit characteristic prices from their current equilibrium levels to the points at which the quantity demanded of each characteristic just reaches zero.[6] This is true because an increase in the price of a visit (p_v) to the point where the demand for visits just falls to zero automatically causes the demand curve for each characteristic to shift to the left until the quantity demanded at the given equilibrium implicit price just reaches zero.

[6] A necessary condition for measuring benefits of changes in p_v in characteristics markets is that: $\partial U / \partial v \mid_{z_1,\ldots,z_m = 0} = 0$. By using the sequential procedure for evaluating the benefits of multiple price changes, one can calculate the sum of changes in areas under the demand curves in all markets experiencing price changes. In each market, the demand curve is conditioned on all previously considered price changes.

The existence of implicit markets for quality characteristics in the HTC model is what distinguishes this model from the traditional TC model. Implicit prices are derived for characteristics (treated as choice variables), but these prices are assumed to be either constant or dependent only on the supplies of characteristics, which are assumed to be fixed at each site. Technological factors influence the supply of characteristics at a given site, however, and these factors tend to differ from one site to another; for example, the technological factors that may influence the supply of a fishing success-rate characteristic include the stock of fish and the quality and quantity of fish habitat. For scenery, the technological factors might include the density of trees along the river, the geographic features of the surrounding area, and the number of acres of wilderness adjacent to the river (or the ratio of wilderness to developed acres). These technological factors at any given site may be fixed in the short run, but they might be altered in the long run. Changes in technology will result in shifts in characteristic supply curves. Any such relationships between technological conditions and utility-yielding quality characteristics must be specified outside the HTC model.[7]

The Household-Production Method

The HP method is not necessarily restricted by the inability to endogenously specify relationships between technological factors and quality characteristics. A cost function is specified for those characteristics partially controllable by recreationists (henceforth called endogenous characteristics). If exogenous technological factors were included in the cost function, then the marginal cost (supply) equations for the endogenous characteristics would depend on these technological factors. Hence, the relationships between technological (that is, environmental) conditions at a site and the supplies of endogenous characteristics may be specified directly within the model. This means that the HP framework can be used to estimate the benefits to recreationists of exogenous changes in technology (or environmental quality).

In the HP framework, the recreationist is taken to be both a producer and a consumer of nonmarket goods (commodities). In Bockstael and McConnell's (1983) formulation of the HP model for sport fishing, the angler is assumed to both produce and consume the fish-catch rate (measured in terms of catch per trip or catch during a given period). Given the environmental conditions at the site, the available fishing equipment, and the angler's level of experience, the fish-catch level (z_1) can be produced by combining purchased fishing goods and fishing time. The angler is also assumed to both produce and consume the fishing trips taken during the given period. Total fishing trips (v) are produced by combining purchased transportation goods and travel time. Technological factors that may influence how many trips the angler takes with a given bundle of inputs include the distance between the angler's residence and the site, and the transportation used.

[7] Rosen (1974) shows that when firms are not identical, the cost function is defined on attributes that differ from one firm to another, such as factor prices and technological conditions. The structure of production can then be identified through fitting characteristic supply equations derived from the cost function. The implicit price equations in such a model merely connect the points of intersection of supply and demand curves. To fit the hedonic price equation, observed prices are simply regressed on characteristic quantities by using the best fitting functional form. This procedure does not seem to be applicable for developing the HTC model because no actual producer of characteristics exists that a cost function can be defined for. "Production costs" in this framework are borne by the consumer.

Marginal costs are treated as implicit prices for commodities in this framework and give the minimum costs for obtaining one more unit of a commodity. Marginal costs are derived by partially differentiating the cost function for each commodity. In the HP model, as in the HTC model, the optimal price-quantity combination in each commodity market is defined at the point of intersection of supply and demand curves. But unlike the HTC method, the HP method does not use the price of a fishing experience to infer implicit prices for endogenous quality characteristics, such as the fishing-success rate. Instead, the HP method separates the fishing experience into two parts—the fishing trip itself and the sport-caught fish. A separate, but not necessarily independent, implicit price (or marginal cost) function is specified for each of these commodities.

Given the implicit price (supply) functions for fishing trips (v) and sport-caught fish (z_1), one can derive the commodity demand equations by maximizing utility, $U = U(v,z_1,\bar{z},y)$, subject to the implicit budget constraint, $I = p_v\, v + \pi_1 z_1 + y$, where p_v and π_1 are equilibrium-implicit prices and $\bar{z}$ denotes exogenous quality characteristics. The demand equations for fishing trips and fish catch at a given site during a given period are defined on the implicit prices for v and z_1 and on the exogenous quality characteristics ($\bar{z}$) and implicit income (I). They are written as:

$$v = G_v(p_v(r_v,w,v,e_v),\ \pi_1(r_1,w,z_1,e_1),\bar{z},I)\ \text{, and}$$

$$z_1 = G_1(p_v(r_v,w,v,e_v),\ \pi_1(r_1,w,z_1,e_1),\bar{z},I)\ ,$$

where r_v and r_1 are market prices for the market transportation and fishing goods, respectively; w is the opportunity cost of both travel and fishing time; and e_v and e_1 are technological conditions influencing angler productivity in each commodity market. Environmental conditions at the site, such as fish density and water quality, may be included as exogenous technology variables in e_1. Several different procedures can be used to estimate the benefits to anglers from changes in exogenous quality variables that appear in the cost function. These procedures are described by Bockstael and McConnell (1983) and Strong (1983).

In the HP model, the angler derives utility from both taking a fishing trip and catching fish. The value of a fishing experience is therefore equal to the combined value of the trip and the sport-caught fish. The average value of a fishing experience is estimated by summing total benefits in both markets and dividing by the number of trips taken. Average values of a sport-caught fish can be estimated by calculating total benefits in the fish-catch market alone and dividing this benefit by the number of fish caught. Because fish catch is treated as an endogenous variable, the marginal value of a sport-caught fish cannot normally be determined in this framework as it can by using the TC and HTC methods.

The HP model is different than the TC and HTC models for sport fishing in that the shadow price per trip is not assumed to be fixed; it is also not assumed that the fish-catch rate at any site is outside the control of anglers. The TC method treats the fish-catch rate as an exogenous quality variable that is weakly complementary to visits, and the HTC method treats it as a choice variable with the supply fixed at any given site. Other quality characteristics that can be treated as choice variables in the HTC model include scenery and congestion. These quality characteristics are treated as exogenous quality variables rather than as endogenous choice variables in both the TC model and the HP model (as part of $\bar{z}$). If the fish-catch rate (z_1) is treated as part of $\bar{z}$ (that is, as an exogenous but utility-yielding quality variable), and if the implicit price of a trip is constant, then the HP model collapses to the TC model, as pointed out by Bockstael and McConnell (1981).

Econometric Considerations

We compared the three methods on econometric considerations, including data needs, estimation techniques, and possible specification biases. The methods were ranked by how much control the recreationist is assumed to have over the quality of the experience. The recreationist is assumed to have least control in the TC method and most control in the HP method. With more control, however, comes more extensive data requirements and greater analytical difficulty. Indeed, as we will show, the TC method requires the least basic data and is generally the easiest method to apply. We found the HP technique to be at the other end of the scale and to require considerably more data and analytical steps for the best results. Analytical difficulties may arise with the HP method in attempts to obtain solutions to highly nonlinear systems of equations. For data requirements and degree of analytical difficulty, the HTC method seems to lie somewhere between the TC and HP methods.

The three methods were compared as if each were applied to develop a model for sport fishing. The common-choice variable in each model was defined as the number of fishing trips taken to a given site. Only one quality characteristic—the rate of fishing success—was used to simplify the discussion. Two reasons for including a catch-rate variable in the model are to obtain estimates of the value of sport-caught fish and estimates of the recreational benefits of changes in either fish catch or the implicit price of a sport-caught fish. We assumed that the utility function underlying each approach was weakly separable in sport-fishing commodities, so that prices of other commodities could be omitted from the demand equations. We also assumed that the TC and HP models were developed for a representative site rather than for multiple sites.

The Travel-Cost Method

A single demand equation is specified for fishing trips to apply the TC method to develop a single-site model. If data are available for several sites, a separate demand equation for each site can be developed or the data can be pooled across sites and a demand equation fitted for a typical site in the sample. For the basic model, data are required to construct variables on the number of fishing trips taken to a given site, the fixed price of a visit, and the income of the user. The price variable is frequently defined as the product of round-trip distance and some fixed cost per mile for transportation. Sometimes the price variable is constructed from actual data on reported per-trip expenditures. The opportunity cost of round-trip travel time can also be included in the price variable.[8]

If the price per visit is defined as the sum of transportation expenses plus the opportunity cost of travel time, then it must be assumed that marginal variations in money and time costs have an identical effect on the demand for fishing trips. It is also assumed that the cost function is linear in the trips variable because the marginal cost equation for trips would be written as $MC_v = m_v + t_v$, where m_v denotes monetary travel costs and t_v is the time cost per trip. If time costs are included in p_v, then the budget constraint (and, hence, the income variable) should include the value of available time, as well as the amount of available money income.

Quality characteristics of a fishing experience (such as the fishing success rate) can be included as exogenous variables in the TC demand equation; but for a fish-catch-rate variable, this approach causes problems. A correlation between the error term of the estimated demand equation and the catch-rate variable is likely and can arise from a correlation between errors of measurement in this variable and the dependent variable.[9] This correlation tends to cause biased parameter estimates. One way to correct for these potential biases is by using an instrumental variable technique.[10]

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[8] The subject of which cost categories to include in the travel-cost variable has received considerable attention in the literature. Hammack and Brown (1974) argue that only cost differentials among recreationists need to be included and that any costs common to all users can be safely omitted. They show that these costs affect only the intercept of the travel-cost demand equation and predict that visits and consumer surplus are the same whether these common costs are included or not. The only difference when common costs are included is that the price paid is higher.

Ward (1984) argues that including any endogenous variables in the construction of the travel-cost variable is likely to result in bias in the estimated price coefficient. He does, however, include exogenous costs—in particular, any entry fees paid at the site—common to all users. Including these common entry fees seems appropriate if the analyst is interested in valuing the site; that is, consumer surplus is the same with or without including these costs, but the value of the site is underestimated if they are excluded.

[9] This problem is discussed in an unpublished paper presented at the Allied Social Science Meetings, New York, December 20-30, 1982, "Estimation of Oregon Sport Caught Salmon and Steelhead Values Via the Travel Cost Method," by William G. Brown, Colin N. Sorhus, and Philip A. Meyer.

[10] If the price variable for visits is calculated by using data on reported expenditures, then the same kind of correlation may also occur between measurement errors in the dependent variable and in the price variable. Using distance traveled and a constant travel cost per mile to compute travel expenditures is one possible way to avoid this specification bias.

An alternative approach to including the catch-rate variable directly in the demand equation has been proposed by Brown and Sorhus (see footnote 9). It requires a two-stage estimation procedure. In the first stage, the values of selected sites are determined from estimates of the total consumer surplus obtained from a TC demand model. Ideally, a set of demand equations (one for each site) is estimated by using simultaneous-equations methods. These ordinary demand equations conditioned on prices (travel costs) for other sites are then used to calculate estimates of consumer surplus for each site. In the second stage, these estimates of consumer surplus for each site are regressed on the total number of fish caught at each site.[11] This second-stage regression provides an estimate of the marginal value of a sport-caught fish. The marginal-value estimate obtained from a linear model represents the fixed marginal value of a sport-caught fish at a typical site in the sample. Both fish-catch data and data on fishing activities from many sites are needed to apply this technique. The fish-catch data by site need not be from the same source as the data on fishing activities that are used to estimate the TC demand model. If weak complementarity between fishing trips and fish catch is assumed, one can use changes in the area under the demand curve for fishing trips to estimate the marginal value of a sport-caught fish, which is what this procedure does indirectly.

The Hedonic Travel-Cost Method

The HTC method provides estimates of the marginal value of a quality characteristic, such as the fish-catch rate, by identifying an implicit market for that characteristic. Although the marginal value of a given quality characteristic is not necessarily measured in the market for visits, as with the TC method, the implicit price of the characteristic is defined by changes in the price of a visit. Thus, even though a close relation is assumed between fishing trips and the fish-catch rate, these are not necessarily assumed to be weak complements.

A two-stage procedure is used to empirically estimate an HTC model. In the first stage, the hedonic price equation for a given zone is specified by expressing the price of a visit to each site as a function of the fixed catch rate at the site and as a function of unknown parameters describing the production technology for the sites. This first-stage equation is estimated with data on per-visit prices and catch rates across various sites visited by anglers from the zone. These data can come from a survey of a sample of anglers from the zone. The estimated hedonic price equation is then used in the second stage to specify a demand equation for visits and one for the catch rate.

The same definition as that used in a TC model for the fixed price of a visit may be used here, and it is just as important in the HTC model to obtain sufficient variability in observed prices across the sample. This means that the sites visited by anglers from a given zone must span a broad enough geographic area. In the TC model, on the other hand, this means that the residences of anglers visiting a given site must span a broad enough geographic area. The sampling methods used for each technique therefore differ.

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[11] Frequently, data are not adequate to estimate a simultaneous-equation model, and a single-equation model for a representative site is fitted using multiple-site data. This has the serious flaw in logic of estimating the first stage under the implicit behavioral assumption that substitute sites do not exist and then, in the second stage, dropping this assumption and attempting to explain differences in estimates of consumer surplus among sites on the basis of quality of the site (fish-catch rate).

Rosen (1974) states that the hedonic price function identifies the offer function where firms are identical.[12] Because the offer function is derived, in theory, from a cost function, a theoretical form for the hedonic price equation should exist. In empirical applications of the hedonic technique, a functional form that fits the data well is usually selected. If a linear function is used, the estimated implicit characteristic prices will be constant for all anglers from a zone. Variability in implicit prices across the sample is required to estimate a demand equation for the characteristic. The only way to obtain different values for an implicit price with a linear hedonic price equation is to fit different hedonic price equations for different zones.

The demand equation for the characteristic, along with the demand equation for visits, can be derived from an explicit, functional form for the utility function, $U = U(v,z_1,y,\gamma)$. As before, v is the number of visits to a particular site and z_1 is the fixed catch per trip at that site. The symbol γ represents unknown taste parameters. In general, the demand for both v and the demand for z_1 depends on the price of v, the estimated implicit price of z_1, fixed income (M), and taste parameters (γ). Because the budget constraint is written as $M = p_v(z_1,\beta)v + y$, where $p_v(z_1,\beta)$ is the estimated hedonic price function and β denotes the estimated "technology" parameters, it follows that the estimated values of p_v, not the actual values, should be used in the demand equations. Estimated values of p_v are determined from the formula, $p_v = p_v(z_1,\beta)$. For a linear P_v equation, the coefficient of z_1 represents the implicit price of z_1. If the implicit price of z_1 is not constant for a given zone (that is, the hedonic price equation is not linear in z_1), then estimates of implicit prices are obtained from the implicit price equation, $p_1 = p_1(z_1,\beta)$.[13]

The Household-Production Method

With the HP method, as with the HTC method, demand equations for fishing trips (v) and the fish-catch rate (z_1) are derived from a utility function specified as $U = U(v_1,z_1,y,\gamma)$. In the HP model, however, the implicit price of z_1 is used directly in the budget constraint, $M = p_v(r_v,w,v,e_v,\beta)v + \pi_1(r_1,w,z_1,e_1,\beta_1)z_1 + y$, where z_1 is the total catch rather than the catch per trip, and β_v and β_1 are unknown technological parameters in each market. For a linear p_v equation, the coefficient of z_1 represents the implicit price of z_1. The implicit price functions for v and z_1 are derived from a cost function for the angler, who is both the producer and the consumer of these commodities.

The need to specify a cost function for the angler makes the basic HP method more data dependent than are the other two methods. Also, analytical difficulties can arise when both the cost function and the utility function are highly nonlinear. Because quantities of outputs (that is, commodities) as well as inputs (market goods and time)

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[12] An offer function defines the unit prices a firm is willing to accept for various designs of a product for a fixed profit level when optimal quantities of each model are produced (Rosen 1974).

[13] A specification bias may result from using the estimated values of prices as exogenous variables in the model because the dependent variable z_1 is used to calculate these prices. An alternative procedure is to specify the characteristic demand equation in its reduced form by solving $z_1 = g_1(p(z_1,\beta), p_v(z_1,\beta),M)$ for z_1 in terms of β and M. Ideally, the complete system of equations should be fitted simultaneously, where the complete system consists of the demand equations for z_1 and v as well as the hedonic price equation for p_v and the implicit price equation for p_1. This method is not applicable, however, because observations on p_1 are not available until the hedonic price equation has been estimated.

are assumed to be endogenous, the complete system of equations includes demand equations for the commodities v and z_1 and demand equations for all inputs used to produce v and z_1. Demand equations for inputs are derived from the cost function, which will generally be defined on input prices, commodity quantities, fixed technological conditions, and unknown technological parameters.

To fit the complete system of equations, one needs data on input prices and quantities, commodity quantities, income, and indicators of technological conditions. Input prices include market prices of market goods and opportunity costs of time inputs. Price and quantity data are needed for all inputs used to produce both commodities (v and z_1). Thus, the additional data required for an HP model, as compared with the data required for a TC or an HTC model, include market prices and total input quantities (rather than just average per-trip expenditures) and data for constructing technological variables. Cross-section data will usually provide enough variability in input quantities and in technological factors that vary among anglers. Obtaining sufficient variability in market prices using cross-section data can be difficult, especially if the survey covers a relatively small geographic area.

As noted earlier both physical and biological indicators of water quality can be included in the model as technological variables. Data from several sites are needed to obtain variability in these quality factors. An HP model can be developed for a representative site from cross-sectional data for various sites.

A potential problem in gathering data to construct an HP model is the difficulty of obtaining independent data on total input quantities used by anglers during a given period. Because both the TC and HTC methods assume a constant price per visit, only data on average expenditures per visit are required to estimate these models. For an HP model, though, total input quantities are needed. It would be helpful if anglers kept a record of their expenses for every trip, so that total input usage variables could be constructed independently of the total trips variable. Also, if catch per trip is not assumed to be constant across trips, then data would have to be obtained on fish catch for all trips taken during the given period.

Constructing the Price Variable

An issue receiving attention in the literature is what types of expenditures to include in the price variable.[14] The price variable should reflect the price that a hypothetical producer might charge for a recreational experience. It should represent the recreationist's marginal willingness to pay for a recreational experience.[15] If a person's actual expenditures on any visit adequately reflect the marginal willingness to pay, it

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[14] The price variable in both the TC and HTC models is defined as the sum of expenditures. Even though this is not true with HP models, what types of input prices to include in the implicit price equations must still be decided.

[15] The traditional explanation for the TC method as described by Bowes and Loomis (1980) suggests that only travel costs should be included in the price variable. There is some question about whether this definition is adequate for a study determining the benefits of quality changes at a site rather than the benefits associated with site accessibility. The use of travel costs as a proxy for an entry fee reflects only the price that a hypothetical owner could charge for access to the site—not for the complete recreational experience. For our discussion, we viewed the hypothetical owner as both a producer of a recreational experience and a transporter of it to the "market place." We tried to determine the marginal willingness to pay value at the market place.

seems reasonable to include in the price variable any expenditures beyond what the person would have otherwise spent (that is, what would have been spent in the absence of recreating). Any goods purchased beyond what would normally be consumed would presumably provide the recreationist with additional utility. This additional utility—in monetary terms—provides a measure of the benefits derived by the recreationist from the experience.

The utility-yielding components of a fishing experience include the trip itself, the sport-caught fish, and the aesthetic attributes of the site (for example, scenery and seclusion). It follows that the price variable in TC and HTC models should include the expenditures for these commodities. Expenditures made to consume the trip itself include costs of operating the vehicle (including time costs), food and lodging costs, and onsite costs (excluding costs associated with fishing activities). Food, lodging, and onsite costs are discretionary, so only those costs over and above what would normally be spent in lieu of recreating should be considered. Aesthetic attributes of a site are consumed through the process of taking the trip, so no additional expenditures are associated with these attributes. The expenditures made to consume the fish catch on a trip would include costs of fishing time, rental equipment, guide service, bait, and so on.

In both TC and HTC models, the fishing experience includes the trip itself plus the quality characteristics of the site visited (which are assumed to be exogenous). Thus, all the expenditures described above should be included in the price variable. The fixed onsite costs for consuming additional quality characteristics may be treated as quasi-entry fees. These entry fees are expected to differ across sites as quality differs. The HTC method assumes that recreationists are willing to pay additional entry fees and travel longer distances (and hence, make more travel expenditures) to obtain better quality recreational experiences. This assumption is implicitly made in the TC method because, by assuming weak complementarity, an improvement in quality shifts the demand curve for visits to the right and thereby increases the price recreationists are willing to pay for a visit.

The HP method divides the recreational experience into two commodities: the trip itself and the sport-caught fish. The price of a visit is thus based on all expenditures except those made to catch fish, which are allocated to the fish-catch commodity. In this framework, all expenditures, including travel costs, are assumed to be determined endogenously—the quantities of market goods and time used depend on fixed prices and technological conditions. Implicit price variables for visits and sport-caught fish are functions of these same variables. In the TC and HTC methods, on the other hand, the price of a visit is usually defined as the sum of actual expenditures on market goods and time. Ward (1984) shows that this procedure may lead to biased parameter estimates in demand equations for visits when discretionary costs (such as onsite expenditures and onsite time) are included in the price variable because of the endogenous nature of these types of expenditures and their likely dependence on distance traveled. Because the HP method treats all market goods and time inputs as endogenous variables, there is no reason to believe that the biases will appear in an estimated HP model.

The Aggregation Problem

One problem common to all empirical studies of consumer demand is aggregation. Normally, an empirical demand equation describes the behavior of a representative, current consumer of the commodity under the observed market conditions because price-quantity data are usually available only for current consumers rather than for all consumers, both current and potential. Thus, when the model is aggregated for current consumers, the resulting market demand curve will not account for new consumers who may begin to purchase the product as the price falls. If the model did account for all consumers, then it would generally be more price elastic than the conditional model estimated with data only for current consumers. The bias in parameter estimates from a conditional demand equation may have serious implications for measuring recreational benefits.

Brown and Mendelsohn (1983) point out that in studies of recreational demand, the use of individual observations on current consumption of a recreational resource results in a demand curve that does not accurately reflect the reduction in participation rates as distance from the site (and hence price per trip) increases. That is, this curve reflects only the decline in use by continuing consumers; it does not account for the decisions of current users to quit participating in a recreational activity as the price of a visit increases. It also does not account for the decisions of current non-users to begin participating in the activity as the price falls. In other words, the entry and exit behavior of recreationists is not reflected along the demand curve, which results in a downward bias in the absolute value of the coefficient on the price variable. Recreational benefits are overstated with such a model.

One way to correct for the bias from not accounting for entry and exit behavior is to apply the common zonal-average method of estimating a TC demand curve. Zones around each site are defined such that individuals in the same zone face similar prices per visit. The dependent variable is defined by per-capita participation rates for each zone. Within each zone, the dependent variable is calculated by estimating the total number of visits by recreationists from the zone (based on sample observations of total trips per individual and the sampling rate) and dividing this figure by the zonal population. The independent variables are defined as zonal averages, and they are represented by the sample means for each zone.

A demand equation for visits per capita presumably describes the effect increased distance from a site has on participation rates. Because it uses zonal averages rather than individual observations of the price variable, this model also corrects for biases from any correlation between measurement errors in the dependent variable and those in the price variable.[16] One limitation is that some information is lost when individual observations are averaged (Brown and Nawas 1973, Gum and Martin 1975).

[16] This problem does not exist in the HP model because the implicit price of a visit is specified as a function of the fixed input prices and technology variables, none of which should be subject to measurement error.

One way to use individual observations and still account for the declining participation rate with increasing distance is to define the dependent variable for each individual observation on a per-capita basis (Brown and others 1983). How many visits each individual sample observation represents is calculated for the zone by using the same zones as in a zonal-average model; the total zonal population is then distributed across the individual observations. These allocations of zonal population are used as the denominators of the dependent variable for each individual observation. A demand model estimated with these adjusted individual observations may account for declining participation rates with distance from the site, but bias may still result from measurement errors in the price variable.

Two problems are common to both the zonal-average approach and the adjusted individual-observations approach. First, the delineation of zones is somewhat arbitrary; this is a problem if the number of zones or their sizes has any effect on the parameter estimates obtained. Second, it is theoretically more appropriate to use the total number of consumers (both current and potential) rather than total population figures as the denominators of the dependent variables; however, total population data are more empirically accessible than are data on the total number of recreationists.[17]

A demand equation for a representative consumer can be fitted by using the observations for which participation levels are zero along with the other observations in the sample. In a survey of households, many responses will come from recreationists who do not visit certain sites. Hanemann (1981) points out that the visits variable has a discrete probability mass at zero and is highly skewed with a long right tail. For this type of probability distribution, Hanemann (1981) suggests that the recreationist's decision process be modeled as a two-step procedure. The first stage is the qualitative choice of whether or not to participate in a particular recreational activity, and the second stage is the quantitative decision of how many recreational trips to make when the decision to participate has been made. The product of the probability of participation (estimated in the first stage) and the conditional rate of participation (estimated in the second stage) gives the expected participation for a representative consumer.

Neither the zonal-average method nor the adjusted individual-observations method directly models the participation decision (Hanemann's first-stage qualitative decision). Rather, they each attempt to derive the true market demand curve by accounting for differences in participation rates along the demand curve. McConnell suggested that rather than fit a per-capita demand equation, one could use a two-stage procedure, similar to Hanemann's procedure, that would more explicitly model the participation decision.[18] The first-stage model would specify the participation rate for

[17] One way to estimate the total number of recreationists for each zone is to estimate the proportion of the total population in the zone closest to the given site that will visit the site. If the residents of the closest zone face a near-zero price per visit, this proportion should give a good estimate of the percentage of a population that would visit the site if the price were to fall to zero. This percentage estimate can be used to adjust each zone's population to a total-recreationist basis.

[18] Personal communication, Ted McConnell, University of Maryland, Room 2200, Symons Hall, College Park, MD 20742.

each zone as a function of distance. The second-stage model would specify the conditional number of visits for each individual recreationist as a function of distance or price and any other demand determinants. The predicted conditional number of visits could be multiplied by the predicted participation rate for the appropriate zone (which serves as a probability-of-participation variable) to predict the individual's expected participation. (A hypothetical example of this approach is presented in chapter 5, part I.) Although this two-stage approach models the participation decision in a more explicit manner than does the per-capita demand model, the approach does not relate both stages of the decision process to a common utility-maximization problem. As no theoretical basis exists for the first-stage model, the choice of a functional form appears to be arbitrary.

More work must be done to develop unified utility-theoretic models explicitly allowing both discrete and continuous consumer choices. Hanemann (1984) developed discrete and continuous-choice models that he uses when the consumer chooses among various goods differing in price and quality. These models are based on random-utility theory, and the discrete- and continuous-choice models are each derived from a single utility-maximization problem. In these models, discrete choices can be specified using logit, generalized logit, or probit models, depending on the probability distribution used for the random disturbances of the utility function. More similar research is needed to develop a utility-theoretic foundation to explicitly account for the qualitative and quantitative dimensions of recreational behavior.

Policy Considerations

The three methods were evaluated by the kinds of policy questions each can handle. In particular, the usefulness of each model was judged on the quality variables that can be included in the model, which suggested the policy-induced quality changes each model can be used to evaluate and the data needed to apply each model.

Both the TC and HTC models are restricted to evaluating quality changes perceived by recreationists. Quality variables only enter these models through the utility function, and these quality factors directly influence recreationists' choice of site and level of participation at a given site. Quality variables should therefore be defined by the recreationist's subjective evaluation of quality.

The main advantage the HTC method has over the TC method is that an implicit market is defined for each quality characteristic, so that a weakly complementary relationship between each quality characteristic and the visits variable is not necessary to evaluate the benefits of quality changes. The scope of the HTC method for evaluating the effects of policy-induced quality changes is thus somewhat broader than that of the TC method. Another advantage of the HTC method for sport fishing is that a fish catch-rate variable can be included directly in the model because it is treated as an endogenous choice variable. As mentioned earlier, including a catch-rate variable in a TC model can lead to biased parameter estimates. By use of the two-stage procedure of Brown and Sorhus (see footnote 9), the marginal value of a sport-caught fish can be determined from fish-catch data, by site, that need not come from the same source as the data on fishing trips.

Estimates of the marginal value of a sport-caught fish from either a TC or an HTC model may be useful for evaluating the benefits of exogenous changes in fish catch; for example, recreational benefits of an increase in fish stocks or an improvement in habitat and water quality can be determined. Of course, prior knowledge of the effects on fish catch of changes in fish stocks or habitat and water quality is necessary. The effects of these changes can be specified directly in the HP model. Without additional information beyond that provided by an empirical HP model for sport fishing, the benefits of increases in fish stocks or of improvements in habitat or water quality can be evaluated. The HP model provides estimates of marginal values for any exogenous quality factors included as technology variables in the model. Using policy-related variables is desirable in constructing a model for evaluating policy changes.

Marginal values can also be determined for any exogenous quality characteristics included as variables in the utility function in the HP model (as in the TC model). Because fish catch is treated as an endogenous variable in this model, the model does not provide estimates of the marginal value of a sport-caught fish, but it does give an estimate of the average value. Average values are not always appropriate for determining the effects of marginal changes in quantities of a commodity, so the HP model may not be useful for evaluating the effects of changes in fish catch caused by changes in quality factors not included in the model as technology variables. When the relevant policy-related variables are included in the model, the HP model has definite advantages over both the TC and HTC models in the evaluation of policy-induced quality changes.

Summary

We have described the theoretical foundations for three recreation-valuation methods. All three methods can be derived from a constrained utility-maximization problem, and nonmarket values for recreational commodities are inferred from hypothesized relations between these commodities and various groups of market goods. The three methods differ primarily in (1) the decisionmaking processes used to describe the behavior of recreationists and in (2) the role recreationists have in determining the quality of a recreational experience. These distinguishing factors have implications for how each method can be used to measure benefits to recreationists from changes in quality.

The single-site TC model assumes that the recreationist decides only how often to visit the recreational site (or a representative site when multiple-site data are used). Although the recreationist may consider the quality attributes of the site, those attributes are assumed to be completely exogenous to making the decision. By assuming a weakly complementary relation between a quality attribute and the recreationist's participation at a site, one can determine the nonmarket value of the attribute in terms of benefits derived from the recreational experience.

The HTC method sees the recreationist selecting a bundle of quality characteristics that the recreationist would like the recreational experience to contain. After this decision is made, the recreationist decides how many times to visit the site offering that bundle of characteristics. Because each type of quality characteristic is treated as an endogenous choice variable in the HTC model, an implicit market is defined for each characteristic. The nonmarket value of a characteristic can thus be determined by measuring benefits in the market for that characteristic. The implicit price of a characteristic is defined by the additional expenditures a recreationist is willing to make to visit a site offering one more unit of the characteristic. The bundle of characteristics provided at each site is assumed to be fixed.

The HP method drops this assumption for certain types of quality characteristics, such as the fishing-success rate. For certain recreational commodities, including the fishing-success rate and the level of participation at a recreational site, the recreationist is viewed as both a producer and a consumer. Implicit commodity prices are defined by the minimum cost necessary to produce one more unit of the commodity. Included are expenditures on market goods and the opportunity costs of time used in the production process. Nonmarket values of an endogenous quality characteristic (such as the fishing-success rate) may be measured in the market for that characteristic, which is represented by an endogenous supply and demand for each site. With this technique, nonmarket values may also be determined for exogenous quality factors influencing the supply of endogenous characteristics.

Although the TC method makes the most restrictive assumptions about the recreationist's decisionmaking, it has the advantage of being less data dependent than the other two methods. This method usually involves fitting a single demand equation for the recreational activity. Exogenous quality variables can be included in this demand equation. Variability in quality can be found in data obtained for several recreational sites. Variability in the price of a recreational experience can normally be obtained with data for recreationists who traveled different distances to visit each site.

The development of an HTC model requires that the given geographic area where different sites are located be divided into several zones. The recreationists living in each zone must visit several different sites at various distances from the zone that have various quality attributes. Fitting the hedonic price equation for each zone requires that the distance traveled to each site be significantly correlated with the quality attributes of each site. The hedonic price equation fit for a given zone provides a set of implicit prices for the quality characteristics. With implicit price data for several different zones, a demand equation for each characteristic can be fit.

The HP method has the most extensive data requirements of the three methods. Price data for inputs as well as quantity data on both inputs and commodities are required to fit the complete system of input and commodity demand equations. Quantities and implicit prices of commodities, including endogenous quality characteristics, typically vary among recreationists. If exogenous quality variables are included in the model, then data for multiple sites will be required because these data will not differ among recreationists for a given site. Objective quality data can be used to define these exogenous quality variables.

To include any quality variables in either the TC or HTC model, on the other hand, requires data on recreationists' subjective evaluations of quality attributes at various sites. The same is true of exogenous quality variables included in the utility function of an HP model. These quality variables are assumed to directly influence a recreationist's decision to participate. Recreationists most likely base their decisions on how they personally rate the quality of a site.

To use the TC and HTC models in policy evaluation, the relationships between policy-related variables and the subjective quality variables included in the models must first be specified. The HP model thus has a definite advantage for policy evaluation over these other two models when policy-related variables are included in the model as determinants of the supply of commodities. In certain circumstances, the extra effort to construct an empirical HP model would therefore be worthwhile. The HTC method seems to have an advantage over the TC method in evaluating the benefits of quality changes because the condition of weak complementarity does not have to be met with the HTC method.

The availability of data and the types of quality variables to include in a model influence the decision on which method to use in a given situation. The underlying assumptions of each approach should be given careful consideration, especially those on the recreationist's role in determining the quality of a recreational experience. The quality characteristics of interest not only influence the selection of a model but also affect the definitions of price variables.

We briefly discussed the problems of defining prices of recreational commodities and of accounting for both the qualitative and quantitative dimensions of recreational behavior. Further research is suggested on relating discrete- and continuous-choice models to a common, utility-maximization problem.

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Chapter 3: Empirical Results From the Travel-Cost Model: Zonal-Average and Adjusted Individual-Observation Versions

William G. Brown and Ching-Kai Hsiao[1]

In this chapter, we present empirical estimates of travel-cost models for the values of salmon and steelhead fishing in Oregon. The values of salmon and steelhead catch were estimated based on estimates of consumer surplus from the travel-cost models and estimates of fish catch from the Oregon Department of Fish and Wildlife.

Theoretical Relationships Between Angler Benefits and Fish Catch

The estimation of values of salmon and steelhead catch can be greatly simplified if a linearly homogeneous relationship exists between consumer surplus to anglers and fish catch. A question can justifiably be raised, however, on whether a linearly homogeneous relationship between consumer surplus and fish catch per river is consistent with economic theory and utility maximization. Although a complete and comprehensive treatment of this question was beyond the scope and intent of this study,

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a brief analysis indicated that under fairly plausible conditions, a linearly homogeneous relationship can be produced via economic theory. Two main aspects of the necessary conditions are (1) the form of the utility function, if such exists, that will cause consumer surplus to vary proportionally to fish catch; and (2) the kind of budget constraint that will, in combination with the utility function, result in a particular functional form of the demand for fishing days or trips. Although other functional forms for utility can give a similar result, one of the simpler forms is:

$$u = q_2^{\beta_2} q_3^{\beta_3} \tag{1}$$

where $b_2 = b_0 q_1^{b_1} < 1.0$, b_0 and $b_1 > 0$, $\beta_3 = 1 - \beta_2$, q_1 is fish catch of angler, q_2 is quantity of fishing trips, and q_3 is all other consumption goods. This formulation also assumes that catch per unit of effort is not subject to the angler's control,[2] but that the angler has good information about the ratio of catch to effort for given rivers.

By maximizing (1) subject to the usual linear budget constraint $p_2 q_2 + p_3 q_3 = x$, the Marshallian demand function can be solved for:

$$q_2 = \frac{b_0 q_1^{b_1} x^{-1}}{P_2} \tag{2}$$

According to (2), the number of fishing trips is a strictly increasing function of the fish catch expected by the angler. The demand relation in (2) implies that fishing trips would not be taken if the angler did not think the probability of catching fish was greater than zero. At any rate, the consumer surplus from (2) can be estimated only if an upper bound is set for p_2, say $p_2 = TC_{max}$, where TC_{max} is usually set equal to the largest of the observed travel costs. The consumer surplus is directly proportional to fish catch if and only if $b_1 = 1.0$. This same result was also deduced from (1) for the semilog form of the demand function to be used later, but it required a nonlinear budget constraint that was difficult to justify on economic grounds. (Details are available from the authors.)

Estimated Zonal-Average Travel-Cost Demand and Benefits

Freshwater Salmon Angling

Estimates of demand and benefits for freshwater salmon by Sorhus (1980) used traditional zonal-average travel-cost models and were based on the unedited data coded from questionnaires. Contract deadlines with the Pacific Northwest Regional Commission, which funded a 1977 survey of Oregon anglers and the first estimates of demand and benefits, did not permit added checking of the travel-cost data by going back to the original questionnaires.

For this analysis, the data were edited, entirely new distance zones were constructed, and travel-cost variables corresponding to these distance zones were computed based on careful examination of the original questionnaires. By reworking the angling data for freshwater salmon, enough observations were obtained to construct

[2] An excellent treatment of theoretical considerations in wildlife recreation, including the effect of assuming an endogenous versus an exogenous catch rate, is presented by Bockstael and McConnell (1981).

distance zones for nine rivers, as compared to only eight in the travel-cost analysis by Sorhus. Among the various zonal travel-cost models fitted, the following semilog form was judged most appropriate:

$$\ln(\mathrm{TRPSCAP})_i = \underset{}{-1.425} - \underset{(-9.35)}{0.05189}\ \mathrm{RTC}_i + \underset{(2.47)}{0.0001552}\ \mathrm{S\text{-}SEQP}_i$$

$$- \underset{(-6.33)}{1.102}\ X_1 - \underset{(-3.81)}{0.9204}\ X_2 - \underset{(-3.41)}{1.651}\ X_3 \quad n = 37 \quad R^2 = 0.815\ . \quad (3)$$

In this chapter, R^2 and r^2 denote the proportion of variation in the mean-corrected dependent variable explained by the regression. Numbers in parentheses are t-statistics for the coefficients.

In (3), $\mathrm{TRPSCAP}_i$ denotes average salmon-fishing trips per capita from distance zone i to the specified river. RTC_i denotes revised travel cost to zone i with travel time assumed to be worth one-third of the wage rate.[3] (The hourly wage rate for each zonal observation was computed by dividing the average yearly income by 2,000.) The symbol $\mathrm{S\text{-}SEQP}_i$ is the average replacement value per respondent in zone i of fishing and related equipment used for salmon and steelhead angling; X_1 is a dummy variable that took the value of one if the respondents of zone i resided in Multnomah, Washington, or Clackamas County and took the value of zero otherwise; X_2 is a dummy variable that took the value of one if the river was the Rogue River, otherwise X_2 was equal to zero; and X_3 is a dummy variable that took the value of one if the river was the Coos River and was otherwise equal to zero.

Thirty-seven completely new distance zones were constructed and the variables recomputed to fit equation (3). (Sorhus's earlier model was fitted to only 25 zonal observations.) Some observations were either deleted or corrected when errors in coding of the original data were detected. In addition, enough observations were found from the questionnaires to add the Wilson River to the travel-cost model. Despite all these changes, the crucial travel-cost coefficient in (3) remained surprisingly close to the original estimate by Sorhus.

Angler benefits related to fish catch—Our first research efforts in incorporating fish catch directly into the angler demand model for fishing trips were wasted. Our idea was that fishing success acts as a demand shifter with a high fish catch for a given river expected to increase the amount of fishing on that river. But our attempts to augment travel-cost demand models with fish-catch data resulted only in serious problems with specification and estimation. We have not presented details here, but instead have outlined another procedure developed by Samples and Bishop (1985) that gives much better results.

Our version of the Samples-Bishop procedure was to estimate the travel-cost-based demand function for the various rivers in one equation. From this equation, consumer surplus was estimated for each river. Then, the total consumer surplus for each river was regressed against the corresponding fish catch for that river. The procedure is illustrated for freshwater sport salmon and steelhead fishing in Oregon.

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[3] Travel cost per trip includes the estimated variable cost per mile of operating a vehicle times the miles driven plus food and lodging costs incurred while traveling. Costs incurred at the destination are not included.

Table 1—Zonal-average travel-cost estimates of consumer surplus for Oregon freshwater salmon sport anglers, 1977

River	Estimated catch of salmon[a]	Traditional estimate of consumer surplus per river[b]	Gum-Martin[c] estimate of consumer surplus per river[b]	Distance from Portland[d]
		- - - - - - - *Dollars* - - - - - -		*Miles*
Alsea	2,290	399,900	193,800	104
Clackamas	2,149	487,900	161,900	18
Columbia	13,172	1,316,600	1,480,300	10
Coos	573	45,200	45,200	212
Deschutes	3,833	71,400	87,400	65
Rogue	8,864	236,600	247,100	245
Umpqua	4,570	477,100	708,700	172
Willamette	14,222	1,720,400	1,638,100	10
Wilson	4,692	161,200	160,700	38
Total	54,365	4,916,300	4,723,200	

[a] Reported by Oregon Department of Fish and Wildlife.

[b] Estimated from equation (3) (see text).

[c] Gum and Martin 1975.

[d] All distances were assumed to be a minimum of 10 miles.

Relation of estimated angler benefits to salmon sport catch—Estimated net economic benefits and fish catch of Oregon freshwater salmon anglers are shown in table 1 for the nine rivers included in equation (3). For the semilog functional form of (3), consumer surplus for the *ith* distance zone is equal to the predicted participation of zone i divided by the travel-cost coefficient. To see this clearly, write the travel-cost demand function as $q_i = a_i e^{bx_i}$, where q_i is the predicted per capita participation rate of zone i and x_i is the travel cost. The constant a_i is assumed to include the effect of any other variables included in the travel-cost equation.

Show the observed travel cost of zone i by x_i^0. Then $q_i^0 = a_i e^{Gx_i^0}$, and the consumer surplus is by definition the integral of the q-function as x_i ranges from x_i^0 to ∞. That is:

$$CS_i = \int_{x_i^0}^{\infty} a_i e^{Gx_i} \, dx_i = \frac{a_i}{b} \quad e^{Gx_i} \Big|_{x_i^0}^{\infty} = - \frac{a_i e^{Gx_i}}{b} = - \frac{q_i^0}{b} \quad ,$$

and $CS_i = -q_i^0/b$, as indicated.

The traditional estimate of consumer surplus (table 1) was computed by dividing the predicted trips per capita for each distance zone by the travel-cost coefficient from equation (3), multiplying by the zone population, and summing the zonal consumer surpluses for a specified river. In this way, consumer surplus to Oregon freshwater salmon anglers was computed for each of the nine rivers. These estimated angler benefits per river are given in table 1.

By regressing the traditional estimates of consumer surplus for the nine rivers in table 1 as a linear function of fish catch per river ($CTCH_j$), we obtained:

$$CS_j = \underset{(-0.32)}{-58{,}981} + \underset{(4.18)}{100.20}\, CTCH_j \qquad n = 9 \qquad r^2 = 0.714\,. \tag{4}$$

The constant term in (4) is far from being statistically significant because the absolute value of t is less than one. Because using the linearly homogeneous form of (4) offers some advantages, to be discussed later, the constant term was deleted, yielding:

$$CS_j = \underset{(6.84)}{94.05}\, CTCH_j \qquad n = 9 \qquad r^2 = 0.710\,. \tag{5}$$

According to (5), the marginal value of salmon catch is around $94 per fish; however, as only the nine most important salmon fishing rivers are represented in table 1, some adjustments are needed. Also, the degree of homogeneity of the consumer surplus-fish catch relationship might not be one as assumed by (5). To test the hypothesis that the degree of homogeneity was different from one, (6) was fitted:

$$\ln(CS)_j = \underset{(2.05)}{5.477} + \underset{(2.69)}{0.8594}\, CTCH_j \qquad n = 9 \qquad r^2 = 0.562\,. \tag{6}$$

By computing $t = (0.8594 - 1.0)/0.3191 = -0.44$, we find that this small value of t falls far short of significance. Therefore, based on the traditional estimate of consumer surplus and fish-catch data of table 1, the hypothesis that the salmon anglers' consumer surplus is a linearly homogeneous function of fish catch cannot be rejected.

One important aspect of the preceding analysis is that the estimated fish-catch data in table 1 are independent of the data used to estimate the consumer surplus in table 1. Salmon sport-catch data are collected each year by the Oregon Department of Fish and Wildlife and are based on the return of salmon-steelhead punch cards and other information. The consumer-surplus analysis was based on our own survey of about 1.5 percent of Oregon anglers (described earlier).

If net economic benefits to sport salmon anglers are approximately a linearly homogeneous function of salmon catch, then estimating benefits from increasing salmon runs and angler catch is greatly simplified. For example, if a new salmon hatchery on the Coos River could increase the runs of salmon, and if salmon catch were increased by 3,000 fish per year, then the projected increase in benefits would be about $94.05(3,000) ≐ $282,000 per year based on equation (5).

A second method was also used to compute the consumer surplus in the last column of table 1, which was based on the innovative research of Gum and Martin (1975). By employing their approach, we used the observed number of fishing trips per capita, rather than the predicted number of trips per capita, as the basis for

computing consumer surplus.[4] The Gum-Martin procedure has some advantages over the more traditional approach, especially for our purpose of relating net economic benefits to catch, because their procedure is far less sensitive to possible errors in the demand model specification that might cause the angler's use of some rivers to be overestimated or underestimated.

By regressing the Gum-Martin estimate of consumer surplus in table 1 as a linear function of fish catch, we obtained:

$$GMCS_j = \underset{(-0.89)}{-148{,}728} + \underset{(5.09)}{111.50}\ CTCH_j \qquad n = 9 \qquad r^2 = 0.787\ . \tag{7}$$

Again, as for equation (4), the constant term in (7) is not statistically significant with a t-value of less than one. Because the linearly homogeneous form of (7) has advantages, the constant term was deleted, yielding:

$$GMCS_j = \underset{(7.29)}{96.01}\ CTCH_j \qquad n = 9 \qquad r^2 = 0.763\ . \tag{8}$$

The hypothesis that the degree of homogeneity of the relationship between consumer surplus and fish catch was not equal to one was tested by fitting:

$$\ln (GMCS)_j = \underset{(1.88)}{4.0326} + \underset{(3.98)}{1.0178}\ \ln (CTCH)_j \qquad n = 9 \qquad r^2 = 0.694\ . \tag{9}$$

Computing t = (1.0178 - 1.0)/0.2556 = 0.07, we find that this small value of t is far from being statistically significant. Consequently, the hypothesis that the salmon anglers' net economic benefits are a linearly homogeneous function of fish catch cannot be rejected based on the data in table 1.

The estimated fish-catch data in table 1 are independent of the data used to estimate the consumer surplus in table 1; this makes the estimated linearly homogeneous relationship between estimated consumer surplus and fish catch more impressive. The relationship between estimated consumer surplus per river for steelhead anglers and the steelhead catch per river should be examined before we discuss the implications of the estimated values of sport-caught salmon.

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[4] Consumer surplus was traditionally computed for each zonal observation by calculating the area under the demand curve predicted for that zone and the average travel cost observed for that zone. Essentially, the Gum-Martin approach shifts the predicted demand for the observation up or down so that the demand curve passes exactly through the observed quantity-travel cost point. (Although Gum and Martin developed their method for use with individual observations, it is also easily used for zonal-average observations, as in this paper.) As Ward notes (1981), one advantage of the Gum-Martin procedure is that it always yields a nonnegative consumer surplus, in contrast to the traditional procedure where consumer surplus must be set equal to zero for negative predicted quantities.

Steelhead Angling

A unique set of distance zones was constructed around each of 21 Oregon rivers fished by steelhead anglers. There were 81 zones with an average of about four anglers per zone who actually fished in the quarter that they received a questionnaire for. The following semilog demand equation was estimated by ordinary least squares:

$$\ln(\mathrm{TRPSCAP})_i = \underset{(-12.35)}{-2.167} - \underset{(-7.42)}{0.0365}\ \mathrm{RTC}_i - \underset{(-4.48)}{1.043}\ X_1 - \underset{(-2.28)}{1.600}\ X_2 + \underset{(2.66)}{1.109}\ X_3$$

$$+ \underset{(2.76)}{1.025}\ X_4 + \underset{(1.91)}{0.8117}\ X_5 \quad n = 81 \quad R^2 = 0.569\,. \tag{10}$$

Variables in (10) are defined as they were for equation (3). Again, X_1 is a dummy variable that took the value of one if respondents of zone i resided in Multnomah, Washington, or Clackamas County and took the value of zero otherwise.

One difference between the estimated demand for steelhead fishing in (10) and for freshwater sport salmon angling in equation (3) is that the fishing-equipment variable did not come close to being statistically significant in the steelhead fishing demand equation; this emphasized the possible differences between salmon and steelhead angling. Four of the rivers had significant dummy variables, X_2, X_3, X_4, and X_5, representing the Chetco, Deschutes, Nestucca, and Umpqua Rivers, respectively. (Without these dummy variables, per capita fishing effort was consistently underestimated or overestimated on these rivers.)

Although some omitted-variable specification bias can occur by not including some of the income or equipment-related variables in (10), the results of fitting other regression equations that included these variables indicated that the squared error loss for the important travel-cost variable would likely be increased by including these other variables. Because estimated net economic benefits are directly related to the travel-cost coefficient, equation (10) was judged the appropriate equation for estimating net economic benefits.

By following the same procedure outlined for freshwater salmon angling, we computed net economic benefits for each distance zone of each river and summed to obtain the estimated benefits for each of the 21 rivers, (table 2).[5] By regressing the Gum-Martin consumer surplus per river as a simple linear function of steelhead catch, the following ordinary least squares estimate was obtained:

$$\mathrm{GMCS}_j = \underset{(0.85)}{123{,}216} + \underset{(4.38)}{93.62}\ \mathrm{CTCH}_j \quad n = 21 \quad r^2 = 0.503\,. \tag{11}$$

[5] The Gum-Martin approach to estimating consumer surplus should be less sensitive than the traditional consumer surplus to possible specification errors that can cause the consumer surplus for some rivers to be overestimated or underestimated. Consequently, only the Gum-Martin consumer surplus is given in table 2. The traditional consumer surplus presented by Sorhus (1980) has a similar relationship to fish catch, but those equations are not included.

Table 2—Zonal-average travel-cost estimates of consumer surplus for Oregon steelhead sport anglers

River	Estimated catch of steelhead[a]	Total consumer surplus per river[b]
		Dollars
Alsea	6,651	783,800
Chetco	2,756	39,200
Clackamas	5,868	1,214,800
Columbia	3,810	412,800
Coquille	2,521	282,100
Coos	1,541	58,200
Deschutes	9,663	847,500
Hood	2,679	146,400
John Day	2,252	100,400
Nehalem	3,325	150,300
Nestucca	13,465	1,555,700
Rogue and Illinois	12,704	1,150,700
Salmon	2,533	334,100
Sandy	7,445	650,100
Santiam	6,486	1,270,600
Siletz	11,619	321,700
Siuslaw	2,145	512,100
Trask	3,086	627,000
Umpqua	9,213	1,632,200
Willamette	2,349	545,600
Wilson	7,730	1,171,600
Total	119,841	13,806,900

[a] Reported by Oregon Department of Fish and Wildlife for 1977.

[b] Estimated from equation (10) and using the method of Gum and Martin (1975).

Given the low t-value of 0.85 for the constant term and the advantages of a linearly homogeneous functional relationship, the constant term was deleted and (12) was obtained:

$$GMCS_j = \underset{(9.42)}{108.81}\ CTCH_j \qquad n = 21 \qquad r^2 = 0.484\ . \tag{12}$$

To test if the degree of homogeneity was significantly different from one, the double-log equivalent of (11) was fitted to obtain:

$$\ln (GMCS)_j = \underset{(1.57)}{3.4047} + \underset{(4.44)}{1.1356}\ \ln (CTCH)_j \qquad n = 21 \qquad r^2 = 0.509\ . \tag{13}$$

Testing the hypothesis that the coefficient for ln $CTCH_j$ in (13) was equal to one, the value of t was:

$$t = \frac{1.136 - 1.0}{0.2559} = 0.53 .$$

Because this t-value was not statistically significant, even at the 50-percent probability level, the hypothesis of a linearly homogeneous relationship between angler benefits and steelhead catch cannot be rejected.

Ocean Salmon Angling

The procedure used to fit the travel-cost demand model for ocean salmon fishing was essentially the same as for freshwater salmon and steelhead except distance zones were constructed so that respondents within zones had fairly uniform distances to the ocean. There were 21 distance zones with an average of over eight respondents per zone (Sorhus 1980, p. 114). The following equation was the most satisfactory of several that were fitted:

$$\ln (TRPSCAP)_i = \underset{(-5.70)}{-2.508 - 0.01875\, TRVCST_i} + \underset{(1.21)}{0.00006931\, INC_i} \tag{14}$$

$$\underset{(-1.22)}{- 0.1224 \times 10^{-8}\, INCSQ_i} \quad n = 21 \quad R^2 = 0.661 .$$

In (14), INC_i is the average income per respondent for zone i, and $INCSQ_i$ is INC_i squared. The other symbols in (14) are the same as defined in earlier equations, except that no travel-time cost was included in $TRVCST_i$.

The consumer surplus per capita was computed for each zone and then multiplied by the zone's population to obtain the total consumer surplus for each zone. Summing the traditional estimate of consumer surplus for the 21 zones gave a total estimated net economic benefit of about \$13.1 million. The Gum-Martin estimate of consumer surplus was slightly higher at \$13.46 million. Dividing the Gum-Martin estimate by the ocean salmon catch for 1977 yielded \$13.46 million ÷ 260,683 ≐ \$52 per fish. Equation (14) can be criticized for not making efficient use of the data because an average of over eight observations per zone yielded only 21 zonal observations. Efficiency might have been increased by grouping ports by county and constructing distance zones around these ports in the way distance zones were constructed around the individual rivers. We constructed distance zones around six coastal counties: Clatsop, Tillamook, Lincoln, Lane and Douglas combined, Coos, and Curry. The most suitable travel-cost model was:

$$\ln (TRPSCAP)_i = -2.043 - \underset{(-7.10)}{0.01843\, RTC_i} \quad n = 47 \quad R^2 = 0.528 . \tag{15}$$

RTC_i is the revised travel cost with travel time valued at one-third the wage rate. The Gum-Martin estimate of consumer surplus was \$13.726 million. Dividing the Gum-Martin estimate of consumer surplus by the ocean salmon catch gave \$13.726 million ÷ 260,683 ≐ \$53 per fish. An average Gum-Martin consumer surplus per trip of about \$54 was estimated from equation (15) as compared to the \$53 per trip estimated by equation (14).

Effect of Other Factors on Estimated Benefits Per Fish

Many things—such as scenery, access, and congestion—can cause consumer surplus per fish to vary from one river to another. Proximity to the Portland metropolitan area might be an important factor affecting angler benefits; we hypothesized that salmon or steelhead rivers close to Portland would have higher demands and correspondingly higher estimates of consumer surplus per fish caught. We tested the hypothesis by measuring the approximate minimum distance of each river to the Portland metropolitan area; all distances were assumed to be at least 10 miles. Distances from Portland are shown in table 1.

Various models for the consumer surplus per river, as a function of salmon catch and distance from Portland, were fitted. The consumer surplus per river was regressed against salmon catch per river and salmon catch per river times the distance from Portland (DP) in miles:

$$CS_j = \underset{(9.21)}{112.01}\, CTCH_j - \underset{(-2.73)}{0.3224}\, (CTCH \cdot DP)_j \qquad n = 9 \qquad R^2 = 0.860\ . \tag{16}$$

From (16), we can infer that each additional mile from the Portland metropolitan area reduces the average value per salmon by about 32 cents. This estimate of the effect of distance from Portland actually seems too high because a distance of 200 miles reduces the value per fish to less than one-half the value of a fish caught near Portland. One reason the effect of distance may be overestimated is that some of the southern Oregon rivers, such as the Rogue, almost certainly have many anglers from California. Estimating the travel-cost model when a few recreationists from great distances are included in the analysis is quite difficult. Out-of-State anglers were therefore not included in the estimation of travel-cost equations, and no estimate of the out-of-State anglers' consumer surplus is included in tables 1 and 2. If a significantly higher percentage of out-of-State anglers were fishing the Rogue and some of the other southern Oregon rivers, equation (16) would overstate the negative effect of distance from Portland on the average value per fish. Further research is obviously needed to see if reasonably accurate estimates of out-of-State anglers versus Oregon anglers can be obtained for the rivers in tables 1 and 2.

Consumer surplus per river from table 1 (Gum-Martin estimate) was also regressed against the estimated salmon catch per river and the interaction term, which was salmon caught per river times distance from Portland:

$$GMCS_j = \underset{(9.30)}{112.55}\, CTCH_j - \underset{(-2.53)}{0.2969}\, (CTCH \cdot DP)_j \qquad n = 9 \qquad R^2 = 0.876\ . \tag{17}$$

Results from (17) are similar to those from (16) with an implied reduction in value per fish of about 30 cents for each additional mile from the Portland area. The coefficient for the distance variable, DP, by itself was not statistically significant for either the traditional or the Gum-Martin estimate of consumer surplus, although the DP coefficient did have the expected negative sign.

A more realistic estimate of the effect of DP was obtained from the steelhead data, possibly because of the greater number of observations available for the steelhead streams—21 vs. only 9 for salmon. At any rate, one of the better fitting linear models was:

$$\underset{}{GMCS_j} = \underset{(6.39)}{126.6\ CTCH_j} - \underset{(-1.10)}{0.1637\ (CTCH \cdot DP)_j} \quad n = 21 \quad R^2 = 0.515\ . \qquad (18)$$

According to (18), each additional mile from Portland reduces the value of a fish by about 16 cents, or by $16 for each 100 miles. Thus, consumer surplus per fish is estimated from (18) to be only about $94 per steelhead at 200 miles from Portland as compared to about $125 per steelhead at only 10 miles from Portland. This estimate has to be considered very rough, given that the consumer surplus for fishing along southern Oregon streams may be underestimated because of a larger percentage of California anglers. Furthermore, some anglers prefer chinook salmon over coho, and total salmon catch cannot reflect such preferences. In addition, although the anglers in our analysis fished primarily for either salmon or steelhead, a stream that offered a higher probability of catching both might have been preferred.

We examined creel-census data on catch and effort for the Deschutes and the Alsea Rivers. The creel census provided more accurate estimates of catch than did the catch data in tables 1 and 2, which were based primarily on salmon and steelhead tag returns. The creel census also provided much more accurate data on total fishing effort than did the data collected by Sorhus and others (1981), which provide the basis for the consumer surplus estimated in tables 1 and 2. The shortcomings of our data are illustrated by creel-census data for the Deschutes River. Creel-census data indicate that the 1977 catch of adult spring and fall chinook salmon was 1,459 adults and 915 jacks; however, the catch estimated from salmon and steelhead tags was 3,383 (from table 1). In addition, salmon fishing trips to the Deschutes were apparently underestimated by our relatively small 1977 survey of Oregon anglers; the result was too small an estimate of consumer surplus (table 1). Once we had the 1977 creel-census data for the Deschutes, a more realistic estimate of consumer surplus per fish could clearly be computed for the Deschutes by dividing the Gum-Martin estimate of consumer surplus (table 1) by an "adult salmon equivalent" catch based on census data. (If three jacks were equivalent to one adult salmon, then an adult-equivalent catch would be about 1,764.)

A somewhat more accurate estimate of value per salmon caught in the Deschutes is $\$87{,}400 \div 1{,}764 \doteq \$50$ per fish, although this is still too low because of our underestimate of salmon fishing trips. Of course, such an adjustment to fishing trips would not be possible without the creel-census data. Unfortunately, creel-census data were not available for most of the rivers in tables 1 and 2.

Creel-census data were available for the Alsea River. As was true for the Deschutes River, the 1977 salmon catch in the Alsea was greatly overestimated by the salmon and steelhead tag returns. Creel-census data indicated a catch of 283 adult chinook, 785 jack chinook, 96 adult coho, and 185 jack coho. This more accurate estimate of 1977 catch is far below the 2,290 salmon used in table 1. The overestimate of catch in table 1 was at least partially offset, however, by a similar overestimate of effort from our angler survey; this resulted in a corresponding overestimate of consumer

surplus for the Alsea in table 1. An overestimate of 6,651 for steelhead catch in the Alsea (table 2) is also indicated based on the creel-census data indicating a catch of only 4,599 for 1977. This overestimate of catch for the Alsea appears to be offset by a corresponding overestimate of fishing trips by our relatively small 1977 survey. Thus, the average value per steelhead in table 2 for the Alsea, \$783,800 ÷ 6,651 ≐ \$118, seems consistent with the creel-census data.

For the Deschutes River, we also overestimated steelhead fishing effort compared to the creel-census data. Our overestimate of effort and value for the Deschutes (table 2) appears to have been more than offset by the overestimate of steelhead catch for the Deschutes used in table 2. Thus, the average value per steelhead for the Deschutes computed from table 2, \$847,500 ÷ 9,663 ≐ \$88, seems slightly low based on the creel-census data.

Most of the difference in the average values per fish that can be calculated from tables 1 and 2 is due to sampling error, both in the estimated trips by river and in the catch estimates from salmon and steelhead tag returns. If creel-census data were available for most of the rivers in tables 1 and 2, then both the consumer surplus and the catch estimates could be corrected to give more accurate values per fish by river; unfortunately, creel-census data are available for only a few rivers. Some corrections might also be made by gathering data and information from fishery biologists near the various rivers, but limited time and resources precluded this.

Estimated Demand and Benefits Based on Adjusted Individual Observations Per Capita

Freshwater Salmon Angling

For the adjusted individual-observation approach, each individual observation was first multiplied by the same sample expansion factors used to estimate total salmon or steelhead angling trips. Then, each individual observation was divided by the share of the population in its distance zone. If, for example, five individual observations came from one zone with a population of 40,000, and if the first observation was expanded to represent 500 salmon angling trips, then 500 was divided by 8,000 (40,000 ÷ 5 = 8,000) to give a per-capita participation rate of 0.0625 (500 ÷ 8,000 = 0.0625). This procedure was similar to the traditional travel-cost model based on zonal averages but with only one observation per distance zone.

By following the above procedure for freshwater salmon angling for each of the nine rivers in table 3, we obtained 158 individual observations on participation rates per capita (along with 158 individual reports of travel costs and values for the other explanatory variables). Individual participation rates per capita were expressed as a function of various explanatory variables. The following semilog model was one of the better models fitted:

$$\ln(\text{TRPSCAP})_{ij} = \underset{}{-2.693} - \underset{(-4.44)}{0.02175}\ \text{RTC}_{ij} + \underset{(2.19)}{0.00004939}\ \text{S-SEQP}_{ij} \quad n = 158 \quad R^2 = 0.131\ . \tag{19}$$

Table 3—Estimated consumer surplus by river for 1977 Oregon freshwater salmon sport anglers, based on participation rates per capita

River	Estimated catch of salmon[a]	Traditional estimate of consumer surplus per river[b]	Gum-Martin[c] estimate of consumer surplus per river[b]
		- - - - - - - Dollars - - - - - -	
Alsea	2,290	498,000	459,800
Clackamas	2,149	1,493,400	553,300
Columbia	13,172	3,896,500	3,347,300
Coos	573	190,600	78,900
Deschutes	3,833	111,400	208,900
Rogue	8,864	641,600	557,200
Umpqua	4,570	710,700	1,511,500
Willamette	14,222	3,255,000	3,980,100
Wilson	4,692	123,000	383,000
Total	54,365	10,920,200	11,080,000

[a] Reported by Oregon Department of Fish and Wildlife.

[b] Estimated from equation (19).

[c] Gum and Martin 1975.

The variables in (19) are shown by the same symbols as in the travel-cost model in equation (3); RTC_{ij} is the travel cost of the *jth* observation in the *ith* distance zone and cost of travel time is assumed to be one-third of the wage rate. The variable S-$SEQP_{ij}$ is the replacement value of fishing equipment and related supplies used for salmon and steelhead fishing.

The important travel-cost coefficient in equation (19) is less than one-half in absolute magnitude of its counterpart in the traditional zonal-average travel-cost model (equation 3). This smaller travel-cost coefficient implies a value per trip of nearly $46, which is more than twice the estimate from the zonal-average travel-cost model for freshwater salmon angling (equation 3). One possible problem with equation (19) is the likelihood of a considerable amount of error in the travel costs reported by the respondents in our survey, especially when some trips were made 2 or 3 months before the questionnaire was sent.

A marginal Gum-Martin consumer surplus per fish of about $225 was computed as a result of fitting consumer surplus by river as a linearly homogeneous function of catch (as in tables 1 and 2).

Ocean Salmon Angling

Individual participation rates per capita for ocean salmon fishing were fitted as a function of various explanatory variables. The following regression was one of the more satisfactory models fitted:

$$\ln(\text{TRPSCAP})_{ij} = -2.700 - \underset{(-9.05)}{0.01191}\ \text{RTC}_{ij} \qquad n = 211 \qquad r^2 = 0.282\ . \tag{20}$$

Variables in (20) are shown by the same symbols used in equation (19). The travel-cost coefficient in (20) is less than one-half of the absolute magnitude of the travel-cost coefficient for the zonal-average travel-cost model of equation (15) (same as for freshwater fishing). The smaller absolute value of the coefficient in (20) implies a value per trip of about \$84, or over 50 percent more than the earlier estimate from the zonal-average travel-cost model of equation (15). Similarly, the value per fish is 50 percent more than the estimate from the zonal-average travel-cost model. Dividing the total Gum-Martin consumer surplus estimated from (20) by the total ocean salmon catch for 1977 yields \$81 per fish (\$21.24 million ÷ 260,683 ≐ \$81).

One limitation of benefit estimates based on equation (20) is the measurement error bias in the travel-cost coefficient, as mentioned in the preceding section for freshwater salmon angling. A detailed discussion of the pros and cons of the various estimates is presented in chapter 5.

Summary and Conclusions

Various estimates of consumer surplus per trip and per fish from the zonal-average travel-cost model and from the model for individual observations per capita are presented in table 4. For freshwater fishing, the consumer-surplus estimates based on the individual observations per capita are more than twice as high as the estimates from the traditional zonal-average travel-cost model. For ocean fishing, the consumer surplus estimates from the individual observations per capita were about 40 percent higher.

We believe that the higher consumer-surplus estimates from the individual observations per capita resulted from the bias caused by travel-cost measurement error. A substantial error in reporting trip expenses was likely the result of respondents being asked to list expenditures made for fishing trips that were taken as much as 3 months before they received the questionnaires. Hiett and Worrall (1977) found that marine anglers made substantial recall errors when questioned about their fish catch and fishing effort, especially if questioned more than 60 days after their fishing trip.

If large reporting errors of trip costs occurred, as seems likely, then substantial bias in the estimate of the important travel-cost coefficient also occurred. Various authors (for example, Johnston 1972) have shown that the probability limit of the ordinary least squares estimate of the regression coefficient β is:

$$\text{plim}\ \beta = \frac{\beta}{1 + \sigma_v^2 / \sigma_x^2}\ , \tag{21}$$

where σ_v^2 is the variance of the measurement error in reported travel costs, and σ_x^2 is the variance of the true travel-cost values. Equation (21) shows that a large measurement error causes an underestimate of the travel-cost coefficient, which causes a corresponding overestimate of consumer surplus. It also follows from (21) that the bias

Table 4—A comparison of consumer surplus values for salmon sport fishing, estimated by various methods

Salmon sport fishing	Gum-Martin consumer surplus method[a] Total	Average per fish[b]	Average per trip[c]
	Million dollars	----- *Dollars* -----	
Freshwater:			
Zonal-average, equation (3)	$ 4.723	$ 87	$19
Individual per capita, equation (19)	11.080	225	46
Ocean:			
Zonal average, equation (15)	13.726	53	54
Individual per capita, equation (20)	21.240	81	84

[a]Gum and Martin 1975.

[b]Computed by dividing total Gum-Martin consumer surplus by the total number of fish caught.

[c]Computed by dividing total ocean consumer surplus (per Gum-Martin) by the total number of trips, 253,000 and the total freshwater consumer surplus by 243,000 trips.

from measurement error is substantially reduced by the zonal-averaging process used in the traditional travel-cost model; the reason is that the variance of a mean is equal to σ^2/n, and σ_v^2 in (21) is thereby reduced in the zonal-average travel-cost model while σ_x^2 remains essentially unchanged. Plim β therefore tends to β for travel-cost models with zonal-averages having large numbers of observations. Even for small numbers of observations per distance zone, however, the bias from measurement error is greatly reduced (Brown and others 1983).

The preceding discussion was not meant to imply that the consumer-surplus values from the traditional zonal-average model in table 4 were necessarily the "true" values and any others were false. The true values are, of course, unknown, and the best value of travel time is really not known. If the true value of travel time were actually two-thirds or more of the wage rate, rather than the one-third used in our travel-cost models, then our zonal-average travel-cost models would give too low an estimate of consumer surplus. Nevertheless, based on present knowledge, we believe that the estimates of consumer surplus from our zonal-average travel-cost models are the most reliable and accurate of any travel-cost models fitted for this study.

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Chapter 4: Empirical Results From the Travel-Cost Model: Individual-Observation Approach

Kenneth C. Gibbs[1,2]

Outdoor recreational demand functions have traditionally been based on average participation rates and on average travel costs for various distance zones; but some researchers argue that this averaging can reduce the content of the data set (Brown and Nawas 1973, Gum and Martin 1975). Some reservations have also been expressed about the use of individual observations (Brown and others 1983). It is therefore of interest to compare demand and benefit estimates for salmon angling derived by the unadjusted individual-observation approach with the earlier estimates derived from both the traditional zonal-average and the adjusted individual-observations models from chapter 3. A detailed discussion of the pros and cons of different approaches is presented in chapter 5.

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Estimated Demands and Benefits

Freshwater Salmon Angling Based on Unadjusted Individual Observations

With the unadjusted individual-observation approach, each observation is used in the regression without adjustment to a per-capita basis. The unadjusted procedure uses each of the 158 observations as data points and regresses them without adjustment to the dependent variable. From this method, the following semilog model was chosen as best representing the data:

$$\ln(TRPS)_j = \underset{(11.68)}{1.17} - \underset{(-3.23)}{0.011}\, RTC_j + \underset{(3.09)}{0.00010}\, S\text{-}SEQP_j \quad n = 158 \quad R^2 = 0.11\,. \tag{1}$$

In this chapter, R^2 and r^2 are the proportion of variation in the mean-corrected dependent variable explained by regression. Numbers in parenthesis are t-statistics for the coefficients.

The variables in (1) are defined in chapter 3, except that in (1) only one subscript occurs for each observation. $TRPS_j$ is the number of salmon fishing trips the *jth* person took during the 3-month period in which the person was contacted. RTC_j is the revised travel cost for $individual_j$ with travel time assumed to be worth one-third of the wage rate. $S\text{-}SEQP_j$ is the replacement value of fishing and related equipment used for salmon and steelhead angling by $individual_j$. All estimated coefficients are statistically significant, but the magnitudes differ from previous estimates. The consumer surplus from equation (1) is valued at $61 per trip in the traditional method of calculation; however, a higher value of $92 per trip was obtained by using the Gum-Martin method.

Consumer surplus per trip based on the traditional method of computation was converted to a total value per river by using a procedure similar to that used in chapter 3. The consumer surplus per river was then used as the dependent variable, and estimates by the Oregon Department of Fish and Wildlife of catch by river were used as the independent variable to obtain the following regression:

$$CS_j = \underset{(7.39)}{304.39}\, CTCH_j \quad n = 9 \quad r^2 = 0.80\,. \tag{2}$$

A marginal value per fish of $304 is implied from (2).

Ocean Salmon Angling

The 211 unadjusted observations were used to regress the number of trips taken as a function of explanatory variables. The following semilog model was judged the most indicative of the data:

$$\ln(TRPS)_j = \underset{(10.07)}{0.74} - \underset{(-4.40)}{0.0036}\, RTC_j + \underset{(5.18)}{0.000064}\, S\text{-}SEQP_j \quad n = 211 \quad R^2 = 0.19\,. \tag{3}$$

Again, all estimated coefficients are statistically significant. Average consumer surpluses of $199 per trip (traditional method) and $277 per trip (Gum-Martin method) were calculated. These estimates were higher than those found by using other travel-cost methods.

Consumer surplus per fish can be calculated for ocean salmon fishing by dividing the total consumer surplus by the estimated ocean salmon catch. Total consumer surplus is determined by multiplying the consumer surplus per trip by the total number of ocean fishing trips. Data on ocean catch were obtained from Oregon Department of Fish and Wildlife. Each fish has an estimated average net economic value of $211.

Table 1—A summary of consumer surplus values of salmon sport fishing, estimated by various travel-cost methods[a]

Method	Average consumer surplus[b] Per trip	Per fish
	---------- *Dollars* ----------	
Freshwater:		
Zonal-average	19	87
Individual per capita	46	225
Unadjusted individual[c]	61*/92	275*/411
Ocean:		
Zonal-average	54	58
Individual per capita	84	81
Unadjusted individual[c]	199*/277	211*/269

[a] Zonal-average and individual per capita values are from table 4, chapter 3.

[b] Computed by estimating the total consumer surplus and dividing by the total number of trips or by the total number of fish caught.

[c] All consumer surpluses were estimated by the Gum-Martin (1975) procedure, except for those numbers with an asterisk, which were computed by the traditional method.

Table 1 is helpful for comparing the various estimates of economic value per trip and per fish when different forms of the travel-cost method were used. The three forms of the travel-cost method gave quite different results, and arguments can be made for each of the three approaches. A comparison and evaluation of the travel-cost based estimates are presented in chapter 5.

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Chapter 5: Fitting the Travel-Cost Model by Using Zonal Averages, Individual Observations, and Adjusted Individual Observations

Part I: Potential Weaknesses of the Unadjusted Individual-Observation Travel-Cost Model

William G. Brown and Ching-Kai Hsiao[1]

One advantage of estimating consumer surplus based on individual observations is that the data are not averaged, which reduces the informational content of the basic data set; that can be important if explanatory variables other than travel cost are included in the recreational-demand function (Brown and Nawas 1973, Gum and Martin 1975). Unfortunately, a corresponding disadvantage of using individual observations occurs if appreciable errors are made by some respondents in reporting their travel costs; these errors will cause bias in the estimated travel-cost coefficient—the well-known "measurement error" problem (Johnston 1972, p. 281-291). We believe some major errors occurred in the travel costs reported by some respondents to our survey, especially for those trips made 2-3 months before the questionnaire was distributed. Reported expenditures for food and lodging differed greatly among the respondents. Some economists have questioned including expenses for food and lodging in the travel-cost variable because the decisions on these costs are regarded

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as discretionary. Transportation costs to a given location generally show little difference because they are determined primarily by distance. Measurement error can be significant in individual travel costs and can lead to underestimating the absolute magnitude of the travel-cost coefficient and subsequent overestimating of consumer surplus (Brown and others 1983).

Averaging several observations can reduce the bias that comes from measurement error. The zonal-average method of estimating the travel-cost coefficient reduces the bias in the individual observation method (Brown and others 1983).

The bias from measurement error may explain why consumer surplus estimates based on individual observations are more than twice as large as estimates from the traditional zonal-average travel-cost model. The unadjusted individual-observation (UIO) approach results in an even larger estimated consumer surplus. We believe that the larger estimated consumer surplus from UIO is caused by two factors: (1) measurement error in travel cost, for the same reasons as already noted for the individual-per-capita approach; and (2) an additional bias in estimating the UIO travel-cost coefficient that occurs because of the way the dependent variable is specified. This second source of bias needs some explanation.

The desire by many researchers to estimate demand from the unadjusted individual observations is understandable. After all, the individual is the one who gains or loses from policies raising or lowering the price of a commodity. Thus, it seems intuitively appealing to estimate demand directly from the unadjusted individual observations rather than from aggregate per-capita figures that might not adequately reflect individual gains or losses from price changes.

Paradoxically, just the opposite occurs for various cases, with much more accurate estimates of the sum of individual consumer surpluses being obtained from the per-capita demand model than from the UIO approach. For example, a serious underestimation of the UIO travel-cost coefficient can easily occur under the following conditions: If the individual demand functions for persons in all distance zones are distributed symmetrically about some population-mean demand function, then only those persons with demand functions distributed above the population-mean demand function will participate from those zones farther away from the recreational site. Because the few people who do participate will still be taking some trips, however, the estimation of demand with UIO trips as the dependent variable will obscure the declining percentage of participants and result in underestimating the travel-cost coefficient as compared to an adjusted per-capita approach. The following simple case illustrates this possibility. Suppose that the "true" individual demand function for a given recreational activity is:

$$q_i = 6 - 1.0\ TC_i + \alpha_i\ , \tag{1}$$

where α_i is a random "intensity" variable representing the difference in intensity of demand among recreationists. If $E(\alpha_i) = 0$, then the mean individual demand function is $E(q_i) = 6 - 1.0\ TC_i$. Note that α_i is not an error term but, rather, a variable denoting

the difference in intensity or strength of demand among various households. Assume, for illustration, that α_i is a discrete variable taking certain values distributed symmetrically about zero with the following probabilities:

$$E(\alpha_i) = \frac{1}{16} [-4 + 4(-2) + 6(0) + 4(2) + 4] = 0 \ , \tag{2}$$

then the variance of α_i would be:

$$E(\alpha_i\text{-}0)^2 = \frac{1}{16} [(-4)^2 + 4(-2)^2 + 6(0) + 4(2)^2 + (4)^2] = 4 \ . \tag{3}$$

The distribution of α_i implied by (2) is the same as the distribution of the sum that can be obtained from flipping four unbiased coins where a tail is assigned a value of -1.0 and a head a value of +1.0. Thus, the probability is 1 in 16 of obtaining four tails that add up to -4 or four heads and a sum of +4. The probability of obtaining three tails and one head (equal to -2) is 4 in 16, with the same probability for three heads and one tail and a sum of +2. Finally, the probability of obtaining exactly two heads and two tails and a zero sum is 6 in 16. All the above probabilities follow from the binomial expansion, which is shown in some probability or statistics textbooks.

Consider equation (1) for the assumed individual demand function, and then consider the hypothetical travel-cost and distance-zone data shown in table 1, generated from equations (1) and (2). For distance zone 1, the expected number of trips per recreationist is 6 - 1 = 5, but some recreationists take more and some take less, depending on their "intensity of demand"; that is, depending on their α_i value. For example, the first line of numbers in table 1 corresponds to α_i = -4; therefore, the number of visits per participant is 6 - 1 - 4 = 1. Because there is only one respondent, on the average, for this α_i = -4, multiplying 1 times 1 times the sample blowup factor of 100 gives the estimated total number of visits of 100 for the first line. For the second line of numbers in table 1, corresponding to α_i = -2, the estimated total number of visits in the next-to-last column is 3 times 4 times the expansion factor of 100, or 1,200. The other numbers for the main distance zone 1 are generated in the same way.

No potential participants are eliminated in zone 1 because the lowest intensity of demand and travel cost do not drive the q_i value to be equal to or less than zero. But for main distance zone 2, where the travel cost increases to 4, the respondent in the first line of zone 2 of table 1 with α_i = -4 has predicted trips of q_i = 6 - 4 - 4 = -2. Because trips must be greater than or equal to zero, zero trips are indicated by such a respondent. For the second line of zone 2 with α_i = -2, exactly zero trips are reported because q_i = 6 - 4 - 2 = 0. Thus, the total number of trips for these four respondents is zero. For distance zone 3 of table 1, with travel costs of $7 per visit, only the five respondents represented by the last two lines of numbers have sufficiently high intensities of demand, with α_i = 2 and α_i = 4, to take one or more trips. Thus, the sample number of participants drops from 16 to 11 to 5 in going from the nearest zone to the more distant zones, where all zones are assumed to have equal populations of 1,600.

Table 1—Observations generated for 3 distance zones where the true individual demand functions are assumed to be $q_i = 6 - 1.0\ TC_i + \alpha_i$, where $E(\alpha_i) = \frac{1}{16}[1(-4) + 4(-2) + 6(0) + 4(2) + 1(4)]$

Main distance zone	Population of main zone	Intensity of demand	Average travel cost per visit	Predicted total visits per participant	Number of respondents	Estimated total visits[a]	Zonal average visits per capita
			Dollars				
		-4	1	1	1	100	
		-2	1	3	4	1,200	
1	1,600	0	1	5	6	3,000	5.0
		2	1	7	4	2,800	
		4	1	9	1	900	
		-4	4	0	1	0	
		-2	4	0	4	0	
2	1,600	0	4	2	6	1,200	2.125
		2	4	4	4	1,600	
		4	4	6	1	600	
		-4	7	0	1	0	
		-2	7	0	4	0	
3	1,600	0	7	0	6	0	0.4375
		2	7	1	4	400	
		4	7	3	1	300	

[a] Assumes a random sampling of 1 percent of the general population and a corresponding expansion factor of 100.

How would the results in table 1 change if the α_i values were distributed differently; for example, if the α_i were distributed normally with mean zero and variance equal to four? Actually, a similar result can be obtained for most symmetric distributions with similar means and variances.

Fitting the UIO demand function by ordinary least-squares in table 1 gives exactly the same regression coefficients as does defining the dependent variable as equal to the average number of trips per participating recreationist in each zone. This observation can be used as many times as the number of recreationists observed for that zone; that is, the average number of trips per recreationist can be used 16 times as the dependent variable in zone 1, 11 times in zone 2, and 5 times in zone 3 to obtain exactly the same regression coefficients as were obtained by fitting the UIO model. The UIO approach clearly gives an estimated travel-cost coefficient that is ideal for estimating the average number of trips per participating recreationist for a given zone,

but not good at all for predicting the total number of trips to be taken in a zone with a given travel cost! The ordinary least squares equation obtained from the UIO approach is:

$$q_i = 5.5862 - 0.6080\ TC_i\ . \tag{4}$$

An average consumer surplus per participating recreationist of about \$20.38 is obtained by computing the traditional consumer surplus from (4) for zone 1. Multiplying \$20.38 by the assumed 1,600 participating recreationists in zone 1 yields an estimated total consumer surplus for zone 1 of about \$32,608. For zone 2, the same procedure gives 1,100(\$8.182) ≐ \$9,000, and for zone 3, 500(\$1.455) ≐ \$728. Thus, a total consumer surplus of about \$42,336 from the UIO approach is obtained.

How accurate is the preceding UIO estimate? It is easily checked by computing the individual consumer surpluses from the assumed true demand function, $q_i = 6 - 1.0\ TC_i + \alpha_i$. For the first line of numbers in table 1, the true individual demand function is $q_i = 2 - tc_i$, and it represents one sample observation. This consumer surplus is equal to (0.5)(1)(1) = 0.5. A true consumer surplus of \$50 is obtained by using an expansion factor of 100. Similarly, for the second line of numbers in table 1, the true demand function is $q_i = 4 - tc_i$, which implies three trips by this type of participant. A true consumer surplus equal to (0.5)(3)(3), or \$4.5 per participant, is computed. Because four observed recreationists of this type are included in line 2 of table 1, the total consumer surplus represented by line 2 is 400(\$4.5) or \$1,800. By following this same procedure for the rest of table 1, a total true consumer surplus of \$30,050 is obtained. In this example, the UIO approach overestimated the true consumer surplus by \$12,286, or about 41 percent.

Of course, the amount of overestimation bias that may result from the UIO approach could vary greatly from the 40 percent in the assumed conditions of table 1. If distances and travel costs are such that the participation for the more distant zones declines more rapidly than is shown in table 1, then an even greater overestimation of consumer surplus could result from the UIO approach. On the other hand, smaller rates of decline would result in a smaller upward bias from using the UIO method.

Comparing the error in estimating consumer surplus from the UIO method with that from the traditional zonal-average travel-cost model is of interest. If the last column in table 1 (the zonal-average visits per capita) is used as the dependent variable, the zonal-average travel-cost estimate of the demand function is:

$$y_i = 5.5625 - 0.760417\ TC_i\ . \tag{5}$$

In (5), the traditional estimate of consumer surplus is 1.51627 × 1,600 ≐ \$24,260. For zone 2, estimated consumer surplus is \$4.1784 × 1,600 ≐ \$6,685 and only about \$60 for zone 3. Thus, a total consumer surplus of about \$31,005 is estimated by the zonal-average travel-cost model—an amount fairly close to the true consumer surplus of \$30,050. The error of estimation was only about 3 percent, which is much better than the 41-percent error in the UIO method.

The specific numerical results from table 1 should not be generalized. The numerical results are presented only to illustrate the consequences that follow from the basic, logical defects of the simple UIO approach. Sampling errors in the data will cause the specific numerical results to change from one sample to another. Nevertheless, the results from table 1 indicate that estimates of consumer surplus from the UIO approach will not be very accurate, on the average, when a significant decline in the participation rate by the population in the more distant zones occurs.

We wondered if conditions existed under which the UIO approach would give accurate estimates of the true demand-function coefficients and of consumer surplus. The only condition we have found that assures accuracy from the UIO approach is where no variation exists in demand among the participants. (In this case, no decline in participation rates with increasing distance would occur until distance became great enough to cause zero participation.) This condition seems rather unrealistic because great variation occurs in the number of trips taken by individuals incurring similar travel costs.

Some empirical evidence exists that the estimates of value from the zonal-average travel-cost model are likely more accurate than the value estimates based on the two individual-observation approaches. In a carefully planned and well-executed study, Crutchfield and Schelle (1978) used a contingent-value approach to estimate consumer surplus. The approach was based on the willingness of Washington salmon anglers to pay and to sell. Crutchfield and Schelle estimate an average consumer surplus based on willingness to sell of $40 per ocean-salmon fishing-day (1978 prices) with a $500 upper limit, $55 per day with a $1,000 upper limit, and $75 per day with a $2,000 upper limit.

In contingent-value studies, estimates of value based on willingness to sell are on the high side as compared to values based on direct questions about willingness to pay, which usually tend to be much lower. Bishop and Heberlein (1979), in their study of 1978 permits for goose hunting for the Horicon Zone of east-central Wisconsin, found an average consumer surplus of $101 per permit based on hypothetical willingness to sell. The average surplus based on willingness to pay was on $21 per permit. Actual cash offers revealed a "true" average consumer surplus of $63.

In a comparison with the Crutchfield and Schelle estimates, Sorhus (1980) used a zonal-average travel-cost model, with no assumed cost of travel time, to estimate an average consumer surplus of $45 per day for Washington ocean sport salmon anglers. The individual per-capita estimates of consumer surplus for both freshwater and ocean angling are 2.42 and 2.24 times as high, respectively, as the corresponding zonal-average estimates of consumer surplus per trip in table 4, chapter 3. Applying this factor to Washington ocean salmon sport fishery gives 2.24 × $45 or about $100 per day—much too high given the Crutchfield-Schelle results.

Because true values are unknown, we cannot state with certainty that any one estimate in table 4, chapter 3, is precisely correct and that other estimates are correspondingly incorrect. Nevertheless, our conclusion, based on econometric considerations and the available empirical evidence, is that the zonal-average estimates seem much more likely to reflect what the anglers would, on average, actually be willing to pay. More research is needed to fully evaluate the estimating methods under various specified conditions.

Part II: Potential Weaknesses of the Zonal-Average and Adjusted Individual-Observation Travel-Cost Models

Kenneth C. Gibbs[2]

The three methods used in this report to estimate the travel-cost demand for salmon fishing yield quite different estimates of consumer surplus. The question is, which is best? Unfortunately, the true value is not known, so a comparison among the three becomes difficult. No arguments about the differences among the estimates are convincing; the underlying properties of the methods themselves must be evaluated. The choice among models must be based on their logical and internal consistency, which sounds simpler than it is. A detailed comparison might be a study in itself. I will concentrate on potential weaknesses of the zonal-average travel-cost model.

While I recognize weaknesses in all methods that estimate something as difficult as economic value of a recreational activity, I believe some cautions should be observed when the zonal-average travel-cost method is used.

Arguments to convince us that the zonal average exhibits less bias than do individual observations concentrate on the relative magnitude of the estimates (Brown and others 1983). The "true" value is calculated, with known data, by using a zonal approach wherein consumer surplus is estimated for each zone and the estimates are summed. An estimate using individual observations is compared to this, and the difference is used as evidence of a bias. A difference is bound to exist. All such arguments become "example specific" in that other examples can be constructed to show the opposite result. This, it seems, is not the direction to spend energy.

One of the obvious outcomes of averaging data is the loss of information. What do these few average observations, used in the statistical estimation, really mean? After all, it is the individual who is making the decision on recreation, not an average over several individuals. Surely, no one knows what a zonal-average decisionmaker is. The aggregation problem in recreational studies must be directly confronted.

Related to the loss of information from the data is a concern for the validity of the statistical properties. It seems misleading to put any degree of faith in a t-value or R^2 when the data have been averaged. The zonal-average model gives an improved statistical fit because much of the variation in the data has been eliminated. For example, the R^2 statistics presented in chapter 3 for both the zonal-average and the adjusted individual methods for freshwater and ocean salmon fishing are as follows:

Method	Freshwater salmon	Ocean salmon
Zonal-average	0.815	0.661
Adjusted-individual	7.130	.207

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Table 2—Estimates of per-unit values for a representative steelhead angler

Commodity	Value per unit: Compensating variation	Equivalent variation
	Dollars	
Fishing experience	21.57	21.25
Fishing trip	.86	.86
Sport-caught fish	25.61	25.25

This formula gives an estimate of the compensating variation on a quarterly basis. The estimates of the value of a fishing experience for a representative angler are shown in the first column of table 2. This was done by using the sample mean values of the variables w and μ in the formula for CV and dividing CV by the sample mean value of z_1. Table 2 also gives the estimated values of a fishing trip and of a sport-caught fish for a representative angler. Each of these values was derived by calculating $CV_1(CV_2)$ for a representative angler and dividing the result by the sample mean value of $z_1(z_2)$.

Of all the per-unit value estimates, probably the most useful is the estimated value of a fishing experience. This value can be used to determine the welfare effects of a change in the number of steelhead fishing trips taken assuming no change will occur in the mean number of fish caught per trip.

The estimated value of a sport-caught fish can be used to determine the welfare effects of a change in total fish catch not induced by a change in the total number of fishing trips taken. This value represents the amount anglers are willing to pay for the right to catch a fish, given that they have exercised their right to visit the site. One place where this value can be used is in a proposed policy-induced change in fish stocks, which would be expected to have some predicted effect on fish catch. One problem with this is predicting the actual effects of changes in fish population on fish catch.

A problem with using any of these value estimates is that they are based on an all-or-none concept; that is, they are computed by estimating the welfare effects of reducing demand to zero. The validity of using these mean values to evaluate the benefits of marginal changes in demand is questionable. Because fishing trips and sport-caught fish are endogenous variables in this framework, marginal values of these commodities cannot be derived from the model presented in this chapter. This model is designed to estimate instead the welfare effects of changes in exogenous variables.

Estimated HP Model Including Policy-Related Variables

Empirical results for the HP model specification including policy-related variables were estimated by using the observations for which quality data were available. Because of the relatively small sample used for this analysis, an estimation technique different from that used in the previous section was necessary to estimate the taste and technology parameters. A two-stage procedure was used wherein the technology parameters were estimated in the first stage and conditional taste parameters were estimated in the second.

To obtain technology-parameter estimates, the ordinary least-squares regression procedure was applied to the two production functions for quarterly fishing trips (z_1) and quarterly fish catch (z_2). They are specified in Cobb-Douglas form as:

$$z_1 = (e)^{\alpha_{10}} (x_1)^{\alpha_{11}} (t_1)^{\alpha_{12}} (e)^{\alpha_{13}d_1+\alpha_{14}d_2+\alpha_{15}d_3+\mu_1}, \text{ and}$$

$$z_2 = (e)^{\alpha_{20}} (x_2)^{\alpha_{21}} (t_2)^{\alpha_{22}} (k)^{\alpha_{23}} (Rel)^{\theta_1} (Sf)^{\theta_2} (Temp)^{\theta_3} (Turb)^{\theta_4} (Res)^{\theta_5} (e)^{\mu_2} ;$$

where the input variables x_1, t_1, x_2, and t_2 are defined as before: x_1 is transportation inputs, t_1 is travel time, x_2 is fishing inputs, and t_2 is fishing time; u_1 and u_2 are random-error terms. The exogenous quality variables included in the z_2 production function were lagged smolt releases (Rel), streamflow (Sf), temperature (Temp), turbidity (Turb), and total nonfilterable residue (Res). These quality variables were believed to influence either adult fish populations or the catchability of fish.[12]

In the z_1 production function, the distance variable d from the model specification used earlier has been replaced with three dummy variables defined as:

$$d_1 = \begin{cases} 1 \text{ if distance to river is less than 30 miles,} \\ 0 \text{ otherwise;} \end{cases}$$

$$d_2 = \begin{cases} 1 \text{ if distance to river is between 30 and 60 miles,} \\ 0 \text{ otherwise; and} \end{cases}$$

$$d_3 = \begin{cases} 1 \text{ if distance to river is between 60 and 90 miles,} \\ 0 \text{ otherwise.} \end{cases}$$

These dummy variables were used because a specification bias might have resulted if d had been used instead.[13]

Another possible specification bias exists in the z_1 production function as a result of constructing the variables x_1 and t_1 by multiplying both average travel time and average input expenditures per trip by the number of trips taken quarterly (z_1). This procedure can lead to a violation of the condition that the error term of the equation for z_1 is uncorrelated with any errors in the explanatory variables x_1 and t_1. Application of a simultaneous equation-estimation procedure (such as the three-stage least-squares procedure) should alleviate the problem of possible biases in the parameter estimates.

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[12] Although dissolved oxygen is an important element of the steelhead habitat, insufficient variability in concentrations of dissolved oxygen occurred across the sample rivers during 1977 to estimate the effects on fish catch.

[13] It can be shown that the relationship between the variable t_1 and d can lead to biased parameter estimates if the z_1 production function including the variable d were estimated. The variable t_1 is constructed by using the formula:

$$t_1 = \frac{2(d)}{MPH} (z_1) ;$$

where MPH is travel speed in miles per hour.

To obtain technology-parameter estimates for this specification of the HP model, we estimated each production function in its logarithmic form by applying the ordinary least-squares regression procedure.

The estimated z_1 production function is written in logarithmic form as:

$$\ln(z_1) = \underset{(0.08991)}{-2.24702} + \underset{(0.08355)}{2.36331}(d_1) + \underset{(0.08951)}{1.19280}(d_2) + \underset{(0.10014)}{0.65843}(d_3)$$

$$+ \underset{(0.04431)}{0.17610}(\ln(x_1)) + 0.82390(\ln(t_1)) \qquad (n = 374)^{14}\ R^2 = 0.76\ .$$

In this chapter, R^2 is the proportion of variation in the mean-corrected dependent variable explained by regression. Numbers in parentheses are standard errors of the coefficients. All coefficients are significant at the 0.5-percent level. Although the hypothesis of CRS can be rejected at the 1-percent level (but not at the 0.5-percent level), CRS was imposed on this model. We hypothesized that the reason CRS can be rejected for a given distance zone (that is, d_1, d_2, or d_3) is that distance, and hence production efficiency, changes along the production curve for that zone. For a given distance, on the other hand, we assumed that the technology for the z_1 commodity would be CRS. We therefore assumed that the above model (in which α_{11} and $\alpha_{12} = 1$) describes production relationships for an average distance in each zone.

The estimating form for the fish-catch production function is given by:

$$\ln(z_2) = \alpha_{20} + \alpha_{21}\ln(x_2) + \alpha_{22}\ln(t_2) + \alpha_{23}\ln(k) + \theta_1\ln(Rel)$$
$$+ \theta_2\ln(Sf) + \theta_3\ln(Temp) + \theta_4\ln(Turb) + \theta_5\ln(Res) + u_2\ .$$

The results from estimating this equation suggested that all the exogenous quality variables cannot be included together in the model, apparently because of high intercorrelations. These intercorrelations suggested that a serious multicollinearity problem exists in the model; moreover, of the five quality variables, only Rel had significant explanatory power. Not only were the coefficients to the other quality variables statistically insignificant, but some of them also seemed to have incorrect signs.

When each of the exogenous quality variables were included separately in the model, both Temp and Sf, besides Rel, had significant coefficients with the correct signs. But when these three variables were included together in the model, only Rel had a significant coefficient, and the coefficient to Sf seemed to have an incorrect sign. Because Rel, Temp, and Sf could not be included together in the model according to these results, the three possible pairs of these variables were tested.

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[14] This portion of the sample included those 374 observations for which $x_1, t_1 = 0$. Estimation of the Cobb-Douglas production function by using ordinary least squares required nonzero values for all variables.

Only the Temp-Sf pair seemed to work well in the model. Two different specifications for the z_2 production function are therefore acceptable statistically. In one, the variable Rel is included; in the other, both Temp and Sf are included. The two alternative estimated production functions are written as:

$$\ln(z_2) = \underset{(1.3568)}{-5.17045} + \underset{(0.08960)}{0.27729}(\ln(x_2)) + 0.72271(\ln(t_2))$$

$$+ \underset{(0.09562)}{0.04163}(\ln(k)) + \underset{(0.11526)}{0.31599}(\ln(Rel)) \quad (n = 34) \quad R^2 = 0.40; \text{ and,} \qquad (1)$$

$$1n(z_2) = \underset{(0.10124)}{0.27859}(\ln(x_2)) + 0.72141(\ln(t_2)) + \underset{(0.11322)}{0.06292}(\ln(k))$$

$$- \underset{(0.39218)}{1.05698}(\ln(Temp)) + \underset{(0.12219)}{0.05550}(\ln(Sf)) \qquad (n = 31).[15] \ (2)$$

Given the above technology-parameter estimates, conditional taste-parameter estimates are determined by means of the ordinary least-squares regression procedure, which is used to estimate each commodity demand equation. The forms of the two commodity demand equations are written as:

$$z_1 = \lambda_1 \frac{\mu}{\pi_1} + e_1 \text{ , and}$$

$$z_2 = \lambda_2 \frac{\mu}{\pi_{21}} + e_2 \text{ ;}$$

where π_1 is the estimated value of the implicit price of z_1, and π_{21} is the estimated value of the implicit price of z_2. Both e_1 and e_2 are random error terms. The variable π_{21} was derived from the estimated z_2 production function in which the lagged smolt-releases variable was included.

Each set of taste parameter estimates shown in table 3 corresponds to a different definition for w.[16] These estimates can be used along with the technology-parameter

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[15] The observations used to estimate each production-function specification were those portions of the complete sample of observations for which quality data were available and $z_2, x_2, k > 0$. Less than one-fourth of the complete sample both caught fish and used market fishing inputs, and quality data were available for only one-third of that subsample. Deleting the observations for which $z_2, x_2, k = 0$ led to biased parameter estimates; but more advanced procedures allowing inclusion of these observations were not applicable because of the small sample sizes.

[16] Because a zero opportunity cost yields implicit prices of zero, and because each implicit price is the denominator of the respective commodity demand equation, the observations where $w_1 = 0$ were dropped from the sample for estimating λ_1 and λ_2. The z_1 demand equation was fitted with the 292 observations from the total 404 where $w_1 > 0$. The z_2 demand equation was fitted with the 40 observations where $w_1 > 0$ and data on smolt releases were available.

Table 3—Estimates of taste parameter

Opportunity cost of time	λ_1	λ_2
1/4 hourly income	0.00245	0.01279
	(.00016)	(.00377)
1/2 hourly income	.00358	.01837
	(.00023)	(.00511)

Note: Numbers in parentheses are standard errors.

estimates to calculate the welfare effects of exogenous quality changes. For a change in smolt releases from Rel^0 to Rel^1, for example, the estimated value of compensating variation per quarter is equal to:

$$CV_1 = \mu^0 - (\pi_{21}^1/\pi_{21}^0)^{\lambda_2} (\mu^0) ;$$

$$\text{where } \pi_{21}^r = 317.6094(w_1^0)^{0.72271} (k_1^0)^{-0.04163} (Rel^r)^{-0.31599}$$

and r = 1, 0. Similarly, the estimated compensating variation for a simultaneous change in streamflow and temperature from (Sf^0, $Temp^0$) to (Sf^1, $Temp^1$) is equal to:

$$CV_2 = \mu^0 - (\pi_{22}^1/\pi_{22}^0)^{\lambda_2} (\mu^0) ;$$

$$\text{where, } \pi_{22}^r = 1.8069(w^0)^{0.72141} (k^0)^{-0.06293} (Temp^r)^{1.05698} (Sf^r)^{-0.05550} .$$

With the Cobb-Douglas model specification, the demand for z_1 was not responsive to quality-induced changes in π_2. Consequently, quality-induced changes in the value of a fishing experience were determined by dividing the estimated quarterly welfare changes by the constant number of trips taken per quarter (z_1^0). Quality-induced changes in the demand for z_2 were determined by using the ordinary demand equation for z_2 in which the estimated implicit price equation with the appropriate quality variables included was substituted for π_2.

We tested the sensitivity of angler benefits and fish-catch rates to quality improvements. Table 4 shows estimates of the percentage increases in mean values per fishing experience and in mean numbers of fish caught per quarter for a 10-percent increase in smolt releases and for a simultaneous 10-percent decrease in water temperature and 10-percent increase in streamflow. The changes in values per visit were the means of changes in compensating and equivalent variations. The variables w, z_1, k, μ, Rel^0, $Temp^0$, and Sf^0 were fixed at their sample mean values to calculate the results shown in table 4. Accordingly, the results are for a representative river and a representative angler and suggest that a 10-percent improvement in water quality induces, on average, slightly more than a 1-percent increase in both benefits and fish-catch rates.

The HP framework can potentially be integrated with any forest-planning model predicting management-induced quality changes. The two HP model specifications presented empirically in this paper do not appear, unfortunately, to be completely compatible with currently available forest-management models.

Table 4—Estimates of the percentage change in the value of a fishing experience and the number of fish caught as a result of improvements in site quality of a representative river

Opportunity cost of time	10-percent increase in Rel: Change in mean value per visit	10-percent increase in Rel: Change in quarterly fish catch	10-percent decrease in temp and increase in SF: Change in mean value per visit	10-percent decrease in temp and increase in SF: Change in quarterly fish catch
	Percent			
1/4 hourly income	1.02	1.05	1.09	1.19
1/2 hourly income	1.02	1.05	1.09	1.21

The first model specification (in which a variable for lagged smolt releases was included) described lagged effects of quality changes on quarterly fish catch. This model can be used to evaluate benefits to steelhead anglers from changes in smolt release from hatcheries. In a forest-management context, perhaps this model could be useful for evaluating the welfare effects on steelhead anglers of management-induced changes in smolt stocks, but only if the effects of changes in smolt production on fish catch are assumed to be similar to the effects of changes in smolt releases. To use the model in forest-management planning or policy analysis, users must assume that mortality rates and migration patterns are similar for wild and hatchery steelhead. Given this assumption, the HP model can be integrated with any forest-management model able to predict the effects of forestry practices on smolt production in given forest streams. Of course, a variable for total fish population in the model is preferable to a variable representing only hatchery fish.

The second specification of the HP model (in which both water temperature and streamflow variables were included) described the immediate effects of water-quality changes on fish catch per quarter. Although this model may be more compatible with current forest-management models, the immediate effects of quality changes on fish-catch rates are probably not as significant as are the lagged effects because young fish are generally more susceptible to changes in water quality than are adult fish.

One problem with both of the alternative model specifications was that some relevant quality variables were not included, either because of a lack of data or because of multicollinearity problems resulting from intercorrelations among the quality variables. The problem of omitted variables led to a specification bias in the parameter estimates. A possible remedy for the multicollinearity problem might be to use a general habitat-quality index composed of some combination (such as weighted average) of all the important quality parameters.

Summary

We have presented the empirical results from an application of Bockstael and McConnell's (1981) HP framework to 1977 data for steelhead sport fishing in Oregon. The framework provided a way to determine the benefits anglers derive from a fishing experience, which are defined as the benefits simultaneously derived from taking the fishing trip and from catching fish. Two nonmarket goods—the number of fishing trips taken and the number of sport-caught fish—were recognized in this model as utility-yielding components of sport-fishing experiences. Both of these commodities were "produced" by the anglers through use of various combinations of market goods and time inputs under a given set of environmental (technological) conditions.

The major distinction between this framework and other recreation valuation techniques was that fish catch was treated endogenously rather than exogenously. This allowed us to include water-quality variables, which can be related to policy-controlled variables, in the model as determinants of fish catch. The HP framework is thus potentially useful for evaluating the benefits of policy-induced quality changes.

Two different specifications of the steelhead fishing HP model were estimated. The first specification does not include policy-related quality variables and was empirically estimated with observations from 29 rivers in Oregon. A nonlinear, three-stage, least-squares procedure was applied to the complete system of structural demand equations to obtain estimates of both taste and technology parameters. These parameter estimates were used to derive estimates of the mean values of a fishing experience in terms of both compensating and equivalent variation. Mean values were also obtained for a fishing trip and for a sport-caught fish by calculating benefits separately in each commodity market. It is arguable whether these mean values of a sport-caught fish would be useful for evaluating marginal changes in fish catch because fish catch was an endogenous variable in this model.

The second model specification included policy-related quality variables and was used to determine the welfare effects of exogenous quality changes influencing fish catch. Because quality data were not readily available for all the sample rivers, this model specification was estimated with data for only eight rivers. A single-equation estimation procedure was used to obtain parameter estimates in two stages. In the first stage, technology-parameter estimates were obtained by applying ordinary least squares to the production functions for fishing trips and fish catch. In the second stage, ordinary least squares was applied to the two commodity-demand equations to derive taste-parameter estimates conditioned on the predetermined technology-parameter estimates. These parameters were used to derive estimates of the compensating and equivalent variations associated with a hypothetical improvement in water quality. Unfortunately, multicollinearity problems prevented the inclusion in the model of all the quality variables at one time. Despite a possible specification bias resulting from omitted variables, these results demonstrated the potential usefulness of the HP framework for analyzing policy changes that will influence the quality of fishing streams in Oregon.

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Chapter 7: Valuing Oregon Salmon by Using a Multimarket, Hedonic Travel-Cost Method

Gardner Brown, Jr.[1,2]

The travel-cost method has been used for years to estimate the value of recreational sites. The driving force behind this method is that people from different origins bear different travel costs to reach a common site. They can therefore be expected to participate at different rates. Two features of this method need to be mentioned. First, the method captures an all-or-none value for the site; that is, it does not provide information about the marginal value of changing the site a little bit by improving its quality in some fashion. Second, in practice, the procedure assumes that all recreationists have the same opportunities to enjoy substitute locations at the same price; substitutions are therefore omitted from the analysis. Omitting substitutes when they in fact exist overestimates the value of improvements at a site and underestimates the loss from quality changes at a site.

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Fortunately, including substitutes in the analysis solves the second problem and also responds to the first problem. Burt and Brewer (1971) were the first to generalize the travel-cost method to many sites, and their study is the point of departure for the analysis below. But, in contrast to Burt and Brewer who assume sites differ only in location, I have included the location and the quality of the sites, the latter measured by expected fishing success at sites.

The Hedonic Travel-Cost Method

I assumed that each recreation site has a bundle of characteristics. Consumers from a given origin, by paying to travel a bit further, can obtain a richer bundle of characteristics. Thus, in the first step of the analysis, the implicit price of one more unit of a characteristic was estimated by a hedonic price equation. This step is the opposite of applying the usual travel-cost method, which features one site attracting visitors from many origins. I picked one origin and estimated the cost of reaching different sites. The derivative of the hedonic price function with respect to each site characteristic from this first-stage regression yielded the implicit price of each characteristic for that market (origin). Because people from different origins (markets) face different opportunities, each time this first step is repeated for a different origin it provides a new set of implicit prices for the characteristics.

In the second stage, the quantity of characteristics each recreationist enjoys was regressed on the estimated implicit prices of the characteristics and other demand determinants, such as income and age. This step yielded a demand curve for each characteristic from which the marginal value of a characteristic was computed.

Put more formally, I assumed that the consumer's evaluation of the quality of sites depends on objectively measurable characteristics. The characteristics (Z_1) of sites, the number of trips taken (N), and all other goods (X) enter the representative individual's quasi-concave utility function:

$$U = U(Z_1, \ldots, Z_n, N, X) .$$

The total private cost of using different sites differs by location even if user fees are not charged. The further the recreation site from the resident, the greater the out-of-pocket costs of getting to the site. The slower the travel, the greater the time costs of the site. The price of the i*th* site providing a vector of characteristics, Z, was the sum of entry fees, f(Z), and travel costs (both time and money costs), T(Z), plus the fixed cost of the trip, a (that is, those costs not changing with quality). The fixed cost was assumed to be invariant to the site chosen.[3] The total cost or price per trip is:

$$V(Z) = a + f(Z) + T(Z) . \tag{1}$$

The budget constraint facing the individual therefore is:

$$M = X + N \cdot V(Z) ; \tag{2}$$

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[3] Implicitly, I assumed that auxiliary goods, such as food and lodging purchased at the site, are constant with respect to characteristics. If the cost of these facilities does consistently differ with characteristics, then the fixed cost of a trip of given length should also be a function of characteristics.

where M is income and X is assumed to have a unitary price. Utility maximization subject to the budget constraint yields the following first-order conditions:

$$U_{Z_i} - \lambda N(f_{Z_i} + T_{Z_i}) = 0 \ , \quad (i\text{-}1,\ldots, n) \qquad (3)$$

$$U_N - \lambda V(Z) = 0 \text{ , and}$$

$$U_X - \lambda S = 0 \ ;$$

where λ is the Lagrangian function associated with (2) and is interpreted as the marginal utility of income.

The sum,

$$f_{Z_i} + T_{Z_i} = \partial V / Z_i \ ,$$

is the marginal price of characteristic Z_i per trip.

The consumer's choice of outdoor recreation, expressed in terms of two simultaneous demand equations, was obtained by combining equations (2) and (3) to give:

$$Z_i = g(f_{Z_i} + T_{Z_i}, N, W) \quad (i=1,\ldots, n) \text{ , and} \qquad (4)$$

$$N = h(V(Z), Z, W) \ ; \qquad (5)$$

where W is a vector of exogenous demand-shift variables, including M. V(Z), the cost of a trip (from equation 5), can be expressed in terms of its component parts.[4] Thus, when the prices are constant, equation (5) can also be expressed as:

$$N = t(f_Z + T_Z, a, Z, M) \ . \qquad (5a)$$

The supply of trips to each origin was assumed to be perfectly elastic; that is, the cost of a second trip to any site was the same as the cost for the first trip. The supply of characteristics at each site was assumed to be fixed (unresponsive to prices) by exogenous factors.

Explicit information was available for the empirical study below on only one relevant site characteristic, fishing success. The intercept term of the first-stage regression picked up the mean effect of the omitted characteristics and was used as a proxy for the price of other characteristics. Because no measure of quantity existed for the omitted characteristic, its demand equation was not estimated. Thus, only two equations were estimated, one for trips and the other for success. The missing data on other characteristics causes a bias in the parameter for success except when the independent variables truly are statistically independent (this is unlikely to occur).

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[4] The more frequently used specifications for the demand equations (4) and (5) are:

$$Z_i = Z_i(f_{Z_i} + T_{Z_i} \ , V(Z), W) \text{ , and} \qquad (4.1)$$

$$N = N(f_{Z_i} + T_{Z_i} \ , V(Z), W) \ . \qquad (5.1)$$

Solving (5.1) for V(Z) and substituting into (4.1) yields (4); likewise, solving (4.1) for f_{Z_i} and T_{Z_i} and substituting in (5.1) yields (5), if it is assumed these functions exist.

Data and Variables

Data

The questionnaires the basic data were drawn from were described in detail elsewhere (see appendix to chapter 1). In brief, a sample of 9,000 was drawn from purchasers of Oregon angling licenses in 1977. The sample was about 1.5 percent of the total angler licenses purchased. Questionnaires were mailed to about 1,200 anglers in the first and last quarters of the calendar year; about twice and three times that number received questionnaires in the second and third quarters, respectively. Just under one-half of the returned questionnaires were usable; a much smaller number of respondents (405) were primarily interested in salmon fishing, and not all responded to questions critical for the analysis. The sample was further reduced to 290 because a minimum number of responses were needed from a given origin; this was necessary to run a first-stage regression, from which the implicit prices were obtained. The minimum acceptable number of observations from any county was arbitrarily set at 5, which limited the study to 14 counties; that is, 14 prices.

Variables

The variables in the model (with their abbreviations in parentheses) were defined as follows:

Distance (AVDN)—The reported round-trip distances from any given county to any given salmon-fishing location (county or site) were averaged across respondents going to the same fishing site to provide an estimate of distance.

Success per hour (DST)—Respondents reported success and effort in the questionnaire. From these responses, the catch at each site per unit of effort was estimated. This was used as the measure of site quality. Success at a site will vary for people of equal fishing skill. People select a fishing site based, in part, on expectations, which I took to be the sample mean of success per hour fished. The actual success of an angler was therefore regarded as the true value plus random variation. Ideally, a site input characteristic, such as fish density, is a more objective variable to use, but this was not available.

Success per hour (ASE)—This is the average catch per hour (DST) aggregated across the sum of the trips taken by an individual to different sites. Each individual in the sample has an ASE.

Initially, I computed the success of an area for other species of fish because I thought this might be a valuable characteristic. The other species were either insignificant or, for steelhead, very highly correlated with salmon success rates, so they were dropped from the analysis.

Trips (N)—Individuals provided the number of times they went salmon fishing during the quarter they were sampled for. An estimate of the number of salmon-fishing trips per year would have been desirable. There may not be much error because 80 percent of the trips were taken during July and August, the period used for this analysis.

Income (INC)—The questionnaire asked respondents to check the income range of the total gross income for their family. The midpoint of each range was used to value INC.

Mileage costs—The first-stage regression estimated prices measured in miles (actually, marginal miles). Under some conditions, the second-stage demand function could be estimated in terms of miles and finally expressed in more conventional dollar terms. Earlier analysis of the data explicitly recognized that recreationists travel in a variety of vehicles, some with low gas mileage and some with high gas mileage. Thus the price of miles differs for individuals. I used the cost-per-mile estimates from the U.S. Department of Transportation:[5]

Autos and pickups	9.75¢/mile
Motor homes and campers	11.60¢/mile

Time cost—Even though most economists agree that the opportunity cost of travel time is a relevant concept, neither a consensus nor a theoretically defensible empirical estimate of the opportunity cost of time during a trip to a recreation site exists. The controversy over the issue is easily accessible elsewhere and will not be discussed here. A basic estimate of time cost is found by estimating a wage rate on the strong assumption that all reported income is earned and further that each respondent works 2,000 hours per year. The wage rate ($/hour) can be transformed into a mileage cost ($/mile), given the rate of travel (miles/hour)—40 or 35 miles/hour if travel is by auto or camper, respectively—and an assumption about what fraction the opportunity cost of time is of the wage rate. This fraction is assumed to be 30 percent of the gross wage, which is on the order of 50 percent of the wage after taxes.

Entry fee (f)—I assumed that higher access costs were associated with higher quality sites, particularly because sea-going charter boats generally provide better quality fishing. The reported costs of guide service, equipment rental, boat launching fees, and fuel represented the entry fee for a site.

Age was tried as an explanatory variable in the demand equations, but it was never significant so it was dropped.

Estimation

In the first-stage regression, equation (1) was run in linear form for each of the 14 counties having five or more anglers in the sample. An illustrative regression for salmon anglers in Washington County is:[6]

$$\text{distance (AVDN)} = \underset{(3.10)}{50} + \underset{(5.49)}{247} \text{ success per trip (DST)} \quad \bar{r}^2 = 0.74 . \tag{6}$$

[5] Unpublished Report, 1976, "Cost of Owning and Operating an Automobile," U.S. Department of Transportation, Federal Highway Administration, Highway Statistics Division, Washington, DC.

[6] The original regression was run in units of catch per hour. The equation was converted to catch per trip based on hours÷trips = 3.45.

In this chapter, $\overline{R}^2$ and $\bar{r}^2$ are the proportion of variation in the mean-corrected dependent variable explained by the regression when corrected for degrees of freedom. Numbers in parentheses are t-statistics. The interpretation of equation (6) is that for a 20-percent increase in success per trip, from 0.30 to 0.36, a salmon angler must be willing to drive 15 more miles:

$$(\Delta \text{ distance} = 247 \cdot \Delta \text{ catch per trip}).$$

In general, nine of the slope or implicit price coefficients were positive (as they should be), and six of those had t-values greater than 1.85. Five had negative slope coefficients, of which only one was statistically significant. All intercept coefficients were positive, and six were statistically significant (t-values greater than 1.85). These results were not particularly good because the original study was designed to collect data for a different purpose than applying the hedonic travel-cost method.

Appropriate data for this type of study are economically acquired by cluster sampling around a significant number of origins. In the first stage, representative hedonic price functions for given groups of people are sought. Each group faces the same market prices; that is, the distance to an expected quality is the same for all members of the group.

I experimented with nonlinear representations of equation (1) by using squared terms for the independent variable, but these did not fit any better, although a couple of exceptions occurred. The coefficient for catch per trip obtained from the first-stage regression provided the implicit prices of catch per trip for each of the 14 counties in the regression. The value of zero was substituted for negative implicit prices on the assumption that zero is a better estimate of the marginal price of success than is a negative value. The constant term in each of the regressions represented the mean price in miles of the omitted characteristics.

In the second-stage regression, the catch per trip at the site where each individual fished was regressed on the estimated implicit price obtained from the regression for the county in which the individual lived. The sample size was 290. Other explanatory variables were number of trips and income. Figure 1 illustrates this regression. Scattered along a horizontal price line (say, price = 247 miles) are all the salmon anglers in some county (Washington) who were in the sample. They went to different places and each place had a different catch per trip.

Equation (7) represents the simplest second-stage regression estimating the demand for success:

$$\begin{aligned} \text{Catch per hour} = \underset{(3.5)}{0.14} - \underset{(-2.54)}{0.2} \times 10^{-4}(\text{PSAL}) - \underset{(-1.65)}{0.14 \times 10^{-2}} \text{ trips (N)} \\ + \underset{(0.88)}{0.34 \times 10^{-6}} \text{ INC} \quad \overline{R}^2 = 0.02\,; \end{aligned} \tag{7}$$

where PSAL is the price of the success rate in miles.

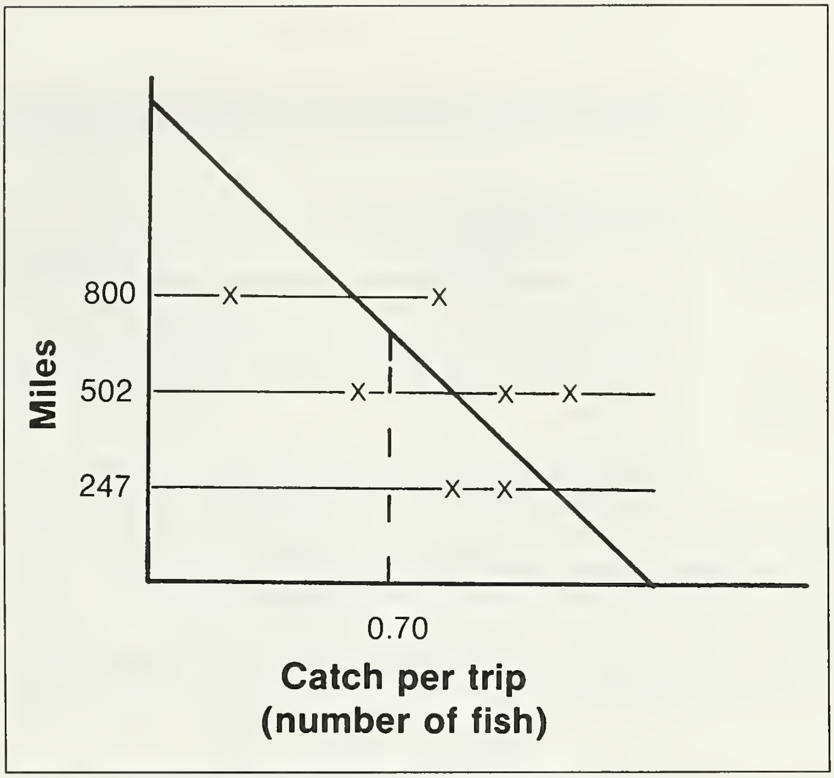

Figure 1—Illustrative second-stage regression where catch per trip is regressed on the estimated implicit price per trip. This represents the demand for fishing success with the price of success measured in miles.

Catch per hour was an unusual dimension to use. I converted to the more usual measure of catch per trip by using an estimate of hours per trip. The analysis showed an average of 3.45 hours per trip, but this was only the actual fishing time. Sorhus (1980) calculated a sample average of 6.8 hours per trip. For comparison with other estimation techniques, the estimates were converted using the ratio of Sorhus' estimate to ours:

$$\left(\frac{6.8}{3.45} = 2.0\right) .$$

The elasticity of demand from (7), evaluated at a mean catch rate per trip of 0.39 by using Sorhus' estimate of 6.8 hours per trip, was 0.18—twice the estimate obtained by using 3.45 hours per trip. This seemed a very inelastic demand. If it is true, or nearly so, then studies computing a constant value of success (as compared to computing a value that is a function of success) will be greatly in error except at the mean. Practically speaking, it means that such studies will badly underestimate the economic losses resulting from success-reducing actions and badly overestimate benefits from success-improving actions.

Taking the inverse of (7), converting to catch per trip, and suppressing the other independent variable yields:

$$\text{PSAL} = \text{constant} - 7{,}245 \text{ catch/trip} , \tag{8}$$

when the Sorhus estimate of 6.8 hours per trip is used (the slope coefficient is 14,490 if hours per trip is 3.45). Equation (8) is illustrated in figure 1.

The sample mean catch per trip was 0.39.[7] I cannot explain this very low rate of success. By using data from the Oregon Department of Fish and Wildlife, I estimated ocean catch per trip to be 1.03 and freshwater catch per trip to be 0.30. Our sample was 58 percent ocean trips and 42 percent river trips. Applying these weights to the respective success estimates from the Oregon Department of Fish and Wildlife yielded a catch per trip of 0.70, which was 2.4 times greater than the sample mean. As a practical matter, this unresolved discrepancy created a great range in the value estimates.

The sample mean PSAL was 502 miles.[8] This means that Oregon salmon anglers in this sample went ("paid") an average of 351 miles to catch one salmon:

$$\frac{502}{\text{fish}} \times 0.70 \, \frac{\text{fish}}{\text{trip}} = 351 \, .$$

Consumer surplus (CS) evaluated at the mean catch per trip is:

$$CS = \int_0^Q f(\overline{Q})dQ - \overline{Q}f(\overline{Q}) = \frac{-\alpha_1 \overline{Q}^2}{2} \, ; \qquad (9)$$

where $\alpha_1 = 7{,}245$,

$\overline{Q}$ = sample mean catch per trip (0.39 or 0.70), and

$f(Q)$ = the inverse of the demand function in (8).

Thus, the consumer surplus was either 550 or 1,773 miles per trip or, respectively, \$55 or \$177 per trip at \$0.10 per mile. This seemed a bit high, unless the \$0.10 mile included some measure of opportunity cost of time. Although \$0.10 per mile was a reasonable estimate of out-of-pocket expenses, perhaps expenses should be adjusted by the number of anglers in the car. Assuming that expenses are shared, either in fact or in effect by each individual taking a turn at providing transportation, seems reasonable.

With equation (9), the average value per fish can be computed for any catch. Evaluated at the mean, the average value of a salmon is:

$$CS/\overline{Q} = -\alpha_1 Q/2 \, .$$

The average value per fish is about \$141 or \$254 at \$0.10 per mile and 0.39 or 0.7 catch per trip, respectively. I think this is a high range.

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[7] Total sample catch equals 428 and total sample trips equals 1,094.

[8] This and other average values are shown in the appendix to this chapter.

The marginal consumer surplus (MCS) addresses the amount a salmon angler would pay to have improved success at a fishing site; for example, what is the value per trip if success per trip increases by 10 percent? From (9):

$$MCS = \Delta CS = - \overline{Q}f'(\overline{Q})\Delta Q \; . \qquad (10)$$

At the average of 0.39 or 0.70 fish per trip, salmon anglers would pay 113 or 355 round trip miles—\$11.30 or \$35.50 per trip at \$0.10 per mile—for an average improvement in fish catch of 10 percent.

After the demand for catch per trip is estimated, the marginal consumer surplus at a level of success can be computed by using equations (8) and (10). The value of improving a site yielding a success rate 25 percent below average can thus be compared with the cost of improvement. Or the value of improving a site yielding a high catch per trip can be compared with the cost of improvement.

The demand equation just discussed had a simple estimate of price. Price was measured in marginal miles. The advantage of such a formulation is that the user may select any unit of mileage cost. For example, if the opportunity cost of time is believed to be 30 percent of the wage rate after taxes and the average speed of traveling is 40 mph, this is equivalent to adding about \$0.06 per mile to out-of-pocket mileage costs.[9]

Caution should be taken with the dependent variable in the demand equation, catch per trip. Many of the anglers in the sample fished at more than one site. Catch per trip for each individual was computed as the average of catch per trip for each of the sites visited by that individual. Strictly speaking, it is the level of success for nowhere in particular. This is just an abstract characteristic of all averages.

The averaging is necessary to circumvent pseudoirrational behavior. When anglers face a fixed and constant unit price for one characteristic, success, each should choose the one site and number of trips to that site that maximizes utility. With x characteristics, there are x sites at most that an angler could visit. But, by the design of the applied model, each angler is restricted to one site no matter how many characteristics there are. Models capturing the value of only one characteristic, such as success, by using data from individuals visiting more than one site, are logically inconsistent.

Anglers choose different sites because they have different amounts of time available during different weeks or because one trip is for a family outing and another is with fishing cronies. If we do not structure a questionnaire to obtain these distinctions, however, we cannot explain why multiple sites are chosen; a real possibility of making inappropriate policy decisions exists. The estimates might show that increasing the density of salmon at one-fish-per-day sites is beneficial—where the one-fish node is an average of better and worse sites actually visited. In fact, densities should perhaps be augmented at the sites hidden by the averaging process, not at the one-fish-per-day site.

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[9] The average annual gross income in the sample was about \$18,000. At a 30-percent tax rate and 2,000 hours worked per year, the net wage rate was \$6.30 per hour.

Table 1—Demand equations for success (catch per hour) under four alternative specifications

	Linear		Log-log					
Item	β	t-value	β	t-value	β	t-value	β	t-value
PSAL			-0.087	-3.69				
PSA	-0.48×10^{-4}				-0.08	-3.58		
PSAF							-0.14	-2.77
N	$-.14 \times 10^{-2}$	-1.64	-.106	-1.36	-.11	-1.35	-.11	-1.42
INC	$.61 \times 10^{-6}$	1.52	.063	.57	.11	1.00	.10	.84
Constant	.13	13.89	-2.54	-2.39	-3.12	-2.90	-2.60	-2.41
$\bar{R}^2$	.17		.04		.04		.03	

The danger discussed above arises when the method is used for valuing characteristics of a location. The problem is inconsequential when only average values are desired, and in this case, no particular reason exists to use a hedonic technique that is expensive because it uncovers a marginal function; a cheaper technique would uncover a constant, the average.

Table 1 summarizes regressions involving various estimates of implicit prices and both a linear and double-log specification. The PSA variable is the dollar measure of miles and includes the marginal opportunity cost of time at 30 percent of the hourly wage rate.[10] The PSAF is the sum of PSA and the marginal fixed cost of a trip, which varies with catch per trip.[11] The fixed cost includes expenditures on guide service, bait, rental equipment, boat launching, and gas for a boat. It excludes camping and lodging fees and food and drink expenses because these do not vary with catch per trip. Even though value is obtained from these latter expenditures, there is little reason for believing that the marginal utility of food varies with marginal catch.

In linear form, the slope coefficients were the same in regressions with the implicit price using distance in money terms (PSA) and those with the price including the fixed cost, which varies with success (PSAF).[12] The logarithmic form of the regression using PSA produced a low estimate of the elasticity of demand (0.08). Apart from a higher elasticity of demand (0.14 vs. 0.08), the log-log demand function with PSAF closely resembled the demand function with PSA. In none of the regressions was income or number of trips statistically significant. Cross-sectional analysis usually does not produce a very high R^2, and the R^2 in all the regressions was very small.

[10] $$\text{PSA} = [0.3\left(\frac{\text{annual income}}{2000\text{ hr}}\right)/\text{mph} + \text{TC}] \cdot \text{PSAL},$$

where $\text{mph} = \left\{ \begin{array}{l} \text{40 if car or pickup} \\ \text{35 if motor home} \end{array} \right\}$, and

$$\text{TC} = \left\{ \begin{array}{l} \text{\$0.0975 if car or pickup} \\ \text{\$0.1160 if motor home or camper} \end{array} \right\}.$$

[11] The equation for the per-capita fixed cost (PSAF) is:

$$\text{PSAF} = \underset{(5.86)}{3.59} + \underset{(2.86)}{12.11}\text{ catch per hour} \qquad \bar{R}^2 = 0.01.$$

[12] One variable is the linear transformation of the other, and PSAF = 12.11 + PSA.

The number of trips (N) taken by a salmon angler was assumed to be a choice variable, so a corresponding demand function for trips was needed. The following semilog specification had the most desirable statistical properties:

$$\ln N = \underset{(8.67)}{1.12} - \underset{(-2.39)}{0.63 \times 10^{-3}} PSA - \underset{(-2.57)}{1.71} \text{ catch per trip} \tag{11}$$

$$+ \underset{(0.76)}{0.35 \times 10^{-5}} INC \quad \overline{R}^2 = 0.03 \; ;$$

where PSA is the marginal price of success each person faces (see footnote 10), and INC is income. Income was not significant but the other variables were. It seemed reasonable that trips should vary inversely with the price of fishing success, but it was less obvious why trips fell as the quality of trip (catch per hour) rose. A quality increase raised the total cost of a trip even when the price per unit of quality was constant. In this model, total cost per trip was the product of price of a characteristic and the level of the characteristic (plus a constant). Trips should fall when the total cost of a trip rises.

Conclusions

Applying a hedonic travel cost to the Oregon sport salmon-fishing data was an experiment with limited success. For the technique to be empirically successful, the number of origins of anglers selected had to be large enough to produce an adequate sample size in the second-stage regression. The nature of the data collected limited us to only 14 sample origins. The original sample was designed with other purposes in mind.

The number of people in each origin had to be large enough and go to different places with sufficient variation in the level of the characteristic to permit a reasonable chance of obtaining a set of regression coefficients for each origin selected. I had neither enough people nor enough different locations to feel confident about the estimates. Care in sample design will have to be taken in future applications of hedonic travel-cost methods.

By using the sample-catch data, I estimated the average value of a trip to be $55 and the average value of a sport-caught salmon at $141. I used the State's catch data to estimate the value of a trip to be $177 and the value of catch to be $254. These estimates were most comparable to Gibbs' estimates (see chapter 4) from unadjusted individual observations. Applying the proportions of freshwater and ocean anglers in my sample to Gibbs' values yielded a value per trip of $141.[13]

In W. Brown's study (see chapter 3), the value of salmon caught in fresh water is about $90, and the value of salmon caught in the ocean is about $50; the precise cost depends on whether actual or predicted trips are used and on the definition of zones. These values are substantially less than my estimates. Because the models were not nested, it was not possible to give a definitive explanation for the difference. Gibbs' study shows that a major difference comes from choosing between individual and per-capita data; this causes differences as small as 70 percent and as large as 300 percent. My results lacked a strong statistical foundation because of the small sample size.

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[13] Weights of 42 and 58 percent, respectively, were applied to a value of $61 per day of freshwater fishing and a value of $199 per day of ocean fishing.

W. Brown obtained an estimate of about $90 per freshwater-caught salmon when time was valued at one-third the wage rate or about $3.00 per hour. He also assumed that cars travel at 45 mph, so this amounts to an additional $0.07 per mile. Introducing time costs in this way increases the value of salmon about 15 percent, from $78 to $90. The price of a mile entered my valuation estimates linearly. Increasing the mileage cost from $0.10 to $0.17 to incorporate the opportunity cost of time caused an increase of 70 percent; it increased the trip and catch values in my study by 70 percent.

Time costs play a less significant role in W. Brown's travel-cost study because his base costs per mile included food and lodging expenses, which were not included in the hedonic approach. In the hedonic approach, food and lodging expenditures were assumed to provide characteristics, such as being well fed, that have utility. Because I could not measure these characteristics, I decided less error would be caused by omitting them. Including food and lodging expenditures in the travel-cost study should increase the value of salmon compared to the results when such costs are excluded; moreover, excluding substitute sites should increase the value of salmon relative to an analysis that includes substitutes, such as the hedonic method. On both these counts, the hedonic-based values should be lower, other things being equal, than the travel-cost-based values. They were not. Probably the best next step is to design a study suitable for the analysis of both the travel-cost and the multimarket-hedonic approaches.

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Appendix

Sample statistics

Total salmon catch	428
Total trips	1,094
Mean PSA	170.45
Mean PSAL	501.76
Mean N	3.77
Mean PSAF	182.56
Mean INC	186.76
Mean PCA	46.23
Mean PCAF	58.34
Total hours	3,777

Chapter 8: Further Comparison of Results From Three Recreation-Valuation Methods

Elizabeth J. Strong and Darrell L. Hueth[1]

We had two objectives for this final chapter. One was to determine whether results obtained from TC, HTC, and HP models were comparable and under what circumstances. The specific results considered were estimates of average values of recreational commodities, such as a fishing experience and a sport-caught fish. The second purpose was to compare the results from the four empirical studies of salmon and steelhead fishing in Oregon presented in chapters 3 through 7. At first glance, these empirical models appeared to be comparable because they were all applied to data on salmon and steelhead fishing activities that came from the same source (that is, the 1977 mail survey of Oregon anglers). Furthermore, each of the models described the behavior of a representative individual in terms of the demand for sport-fishing at a typical site. Closer inspection of these models revealed that they were not directly comparable. Many reasons explain why the commodity value estimates from the different empirical models were not similar.

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Comparability of Results

All three methods can in theory be used to estimate the values of a fishing experience and a sport-caught fish. Whether the unit values obtained from the different models are directly comparable depends on how each model was constructed and on how the values were determined. Constructing a model refers to the variables used, how the variables were defined, and the types of observations used to estimate the model. The valuation procedure refers to the market(s) where benefits were evaluated and whether the procedure provided a marginal or an average value estimate.

We assume here that the common variables in each model were defined in the same way. In particular, we assume that the price of a visit in each model was based on the same types of expenditures. We also assume that the same types of observations were used to estimate each model; for example, we could assume that individual observations of fishing activities were used to estimate each model. If this were true, each model would then describe the behavior of a representative salmon or steelhead angler at a typical site. Under these assumptions, the three models differed mainly in the behavioral and technical assumptions they were based on and in the procedures used to determine the nonmarket value of recreational commodities.

Value of a Fishing Experience

Each of the methods provided estimates of the average value of a fishing experience. This value was assumed to measure the benefits a representative angler derived from a fishing experience at a typical site. This average benefit measure was assumed to include values of any quality characteristics of the experience that were perceived by anglers. The only quality characteristic considered here is the fishing success rate.

With the TC and HTC methods, similar procedures were used to obtain estimates of the average value of a fishing experience. The consumer-surplus area under the demand curve and above the mean price was divided by number of visits made to a single site. These average values probably will not differ significantly between the two methods.

With the HP method, a comparable value per fishing experience was estimated by calculating total benefits in both the fishing trips and fish-catch markets for a representative angler and dividing this benefit measure by the mean number of visits made to a single site. If implicit prices in these markets are fixed and based on the same set of market goods and time allotments as are the prices per visit used in the TC and HTC models, then the value estimates obtained from the latter two models should not differ significantly from the value obtained from the HP model. The main difference between using an HP model with fixed implicit prices and using either the TC or the HTC model to estimate the average value of a fishing experience is that the HP model explicitly accounts for the interrelatedness of the fishing trips and fish-catch commodities. The degree of interrelatedness is indicated by the cross-price effects between the two commodities. The relation between these two commodities can significantly affect the estimated value of a fishing experience.

Value of a Sport-Caught Fish

A different procedure was used in each of the three methods to estimate the value of a sport-caught fish. With the TC method, the two-stage procedure of first estimating recreational benefits and then specifying a relationship between total benefits and fish catch was used. The marginal value of a fish was roughly equal to the increase in total benefits (as calculated in the visits market) resulting from a one-unit increase in the number of fish caught. An estimate of the average value was determined by dividing total benefits in the visits market by the number of fish caught. This procedure for obtaining an average value and the two-stage procedure for obtaining a marginal value (using a linearly homogeneous function) attributed the total utility derived from the fishing experience to the fish catch per visit. If other attributes of a fishing experience, besides the fish catch, give the angler some utility satisfaction, then these two procedures may provide upwardly biased value estimates.

With the HTC method, the value of a sport-caught fish can be estimated in the fish-catch-rate market rather than in the visits market as was done in the TC method. The implicit price of the catch rate was defined as the marginal change in the price per visit with respect to a one-unit increase in the catch rate. If the constant term were zero in the hedonic price function, then the total variation in the price per visit for different sites would be allocated to the implicit price of the catch rate. If this were true, then we would expect the marginal value of a fish from the HTC model to be similar to the value obtained from the TC model, in which there was a linearly homogeneous relationship between benefits and fish catch. Otherwise, the estimated marginal value of a fish from the HTC model would be expected to be lower than the value from the TC model because part of the price variation in the HTC model would be assigned to the other utility-yielding attributes of the fishing experience. The same relationship between the two models held for average values per fish. An average value was obtained from the HTC model by dividing total benefits in the catch-rate market for a representative angler by the mean catch rate.

Like the HTC model, the HP model provided an estimate of the average value of a sport-caught fish on the basis of benefits measured in the fish-catch-rate market alone. Here, though, the implicit price of a sport-caught fish was determined solely on the basis of the market goods and time allotments used for catching fish. Thus, this implicit price might not be the same as the implicit price used in the HTC model. If they were similar, then similar average-value estimates would be expected from both models.

Because the average value provided by the HP model is based only on benefits measured in the catch-rate market, it was expected to be lower than the average value obtained from the TC model. A necessary condition for these values to be similar is that the HP model be specified such that the demand for trips falls to zero when the implicit price of fish catch reaches the point where there is zero demand for fish catch. This condition means that the average per-fish value can be calculated by dividing the benefits of a recreational experience for a representative angler at a typical site by the mean catch rate. A similar procedure (shown earlier) was used to obtain an average value estimate from the TC model.

Comparison of Some of the Empirical Results

Differences in definitions of variables and in the types of observations used in the various empirical models presented in chapters 3 through 7 made the results difficult to compare directly. By adjusting some of the results, however, we obtained average-value estimates that could be compared. We first present the average values of a salmon-fishing experience and a sport-caught salmon as obtained from the TC and HTC models. Then, we present average values for steelhead fishing experiences and sport-caught steelhead as obtained from the TC model and the HP model. Reasons for not expecting the value estimates to be similar are highlighted in the following discussions.

Average Values for Salmon Fishing

In chapter 3, several TC demand models were presented. The zonal-average method and the adjusted individual-observation method were applied to separate sets of data on freshwater and ocean salmon fishing. Chapter 4 presented two more TC demand models for freshwater and ocean salmon fishing. These models were estimated by using the unadjusted individual-observation approach. Because individual observations were also used in applying the HTC method presented in chapter 7, the results from that method should probably be compared with the results from the TC models based on unadjusted individual observations (from chapter 4). The data on freshwater and ocean salmon angling were combined in the HTC method to form a single data file on salmon fishing in general. To compare the results from chapters 4 and 7, a weighted average of the values for freshwater and ocean salmon must first be obtained from the two TC models. The weights of 0.42 and 0.58 were used for freshwater and ocean salmon, respectively. These weights were based on the sample proportions made up of each type of fishing activity.

Table 1 presents the average values of a salmon-fishing experience and of a sport-caught salmon that were obtained from both the TC and the HTC models. The values for the TC model were determined by taking a weighted average of the values obtained from the two TC models that were based on unadjusted individual observations. The data on fish catch used to estimate the average value of a fish in these two models were obtained from the Oregon Department of Fish and Wildlife. The average values shown for the HTC model were estimated using data on fish catch per visit that were also from the Oregon Department of Fish and Wildlife.

Table 1—Average per-unit values as estimated from the TC and HTC models for salmon fishing

Commodity	Model: TC	Model: HTC
	Dollars	
Fishing experience	141	177
Sport-caught fish	248	254

The values obtained from the TC model were coincidentally similar to their counterparts from the HTC model. These similarities were not expected, however, for two reasons. First, the price of a visit was defined differently in each of the models. The price used in the TC model was defined as the sum of the costs of operating a vehicle, food and lodging costs incurred while traveling, and the opportunity cost of travel time. The price used in the HTC model was equal to the costs of merely operating a vehicle. Second, different procedures were used to derive the average values. The average value of a fishing experience was obtained from the TC model by calculating total benefits in the visits market for all sites and dividing this consumer surplus measure by the total visits made. The HTC model was used differently to estimate the average value of a fishing experience at a typical site; that is, the total consumer surplus for a representative angler was calculated in the catch-per-trip market. This benefit measure was assumed to represent the total benefits derived by the angler from the fishing experience. To use this procedure, however, it must be assumed that if the catch per trip were zero, then the angler would derive no utility from the fishing experience. Because a utility function was not specified in chapter 7, this hypothesis could not be tested empirically. If other quality characteristics of a fishing experience would give the angler utility even if no fish were caught, then the average value of a fishing experience would probably be understated by the method used in chapter 7.

Both of the factors mentioned above presumably make the value estimates from the HTC model lower than those from the TC model. This was not true with the values presented in the first line of table 1. Perhaps part of the reason is the model specification used in chapter 7, in which the demand for the catch rate at a given site was specified as a function of the implicit price of the catch rate, income, and the number of fishing trips to the site. Because the number of fishing trips was an endogenous variable, a specification bias would clearly occur. The dependency of fishing trips on the implicit price of the catch rate can also lead to biased parameter estimates in this demand equation. A simultaneous-equations technique can be used to determine whether a significant bias resulted from using single-equation techniques to estimate both the demand equation for the catch rate and the demand equation for the number of fishing trips.

Any biases resulting from a single-equation regression technique would have affected the estimated average values from the HTC model shown in table 1. The average value of a sport-caught salmon was determined by dividing total benefits in the catch-rate market for a representative angler by the average catch per trip. The average value obtained from the TC model was determined by dividing total consumer surplus associated with fishing experiences across all sites by total fish catch. This procedure was equivalent to calculating total consumer surplus in the visits market of the HTC model and dividing by the total fish catch. Even if this procedure were used with the HTC model, the average value obtained would not be expected to be similar to the value obtained from the TC model because of the differences in the price-per-visit variables used in each of the empirical models.

Average Values for Steelhead Fishing

The TC and HP methods were both applied to data on steelhead fishing in Oregon. The two empirical models for steelhead fishing presented in chapters 3 and 6 were not directly comparable, however, because the TC model in chapter 3 was estimated with zonal observations on visits per capita, and the HP model in chapter 6 was estimated with individual observations of participating steelhead anglers. Also, the prices were defined differently in each of these two models.

The HP model divides the fishing experience into two commodities with different implicit prices—the fishing trip and the fish catch per trip. The single price variable used in the TC model should thus be defined on the same basis as both of the prices in the HP model to obtain comparable values of a fishing experience from the two models. The implicit price of a fishing trip in the HP model for steelhead fishing was based on the cost of operating a vehicle, the cost of food and lodging while traveling, and the opportunity cost of travel time. These are the same expenditures included in the price variable used in the TC model. To provide comparable results for the average value of a fishing experience, however, this latter price variable must also include expenditures on fishing supplies and fishing time costs, because these on-site costs were used to determine the implicit price of a sport-caught fish in the HP model.

When the two factors discussed above are considered, the average value of a fishing experience from the TC model would be expected to be lower than the average value from the HP model. That this was not true with the values presented in table 2 is surprising. Perhaps this was due partly to the TC model being applied to data from only 21 rivers, while the HP model was applied to these same data plus data from 9 additional rivers. These 9 additional rivers were apparently less popular than the other 21, so their inclusion could have caused a lower value for an average fishing experience.

Some reasonable explanations exist for the remarkable difference between values from the TC and HP models for sport-caught steelhead (table 2). First, the fish-catch data used to determine an average value from the TC model were from the Oregon Department of Fish and Wildlife, but the data used to construct the fish-catch variable in the HP model were from the angler questionnaires. The Oregon Department of Fish and Wildlife data implied an average catch per trip of 0.24, whereas the angler survey data implied a much higher average catch per trip of 0.81. It was therefore not surprising that the HP model provided a considerably lower estimate of the average value of a fish than did the TC model.

Table 2—Average per-unit values as estimated from the TC and HP models for steelhead fishing

	Model	
Commodity	TC	HP[a]
	Dollars	
Fishing experience	27	21
Sport-caught fish	115	25

[a] The means of compensating and equivalent variation estimates for a representative angler.

We used the above two estimates of average catch per trip to convert the $25-value per fish to something more comparable with the $117 obtained from the TC model. By multiplying $25 by 0.81 and dividing the product (value of fish catch per visit) by 0.24, we obtained a revised per-fish value of $84, which is much closer to the $115 obtained from the TC model. Two possible reasons why this revised value is still lower than the value obtained from the TC model are that (1) the average value obtained from the HP model was based only on the benefits associated with catching fish, rather than on the benefits associated with the whole fishing experience; and (2) including the 9 additional rivers in the sample for the HP model may have resulted in a lower per-fish value as compared with the value obtained using data across the subset of 21 rivers.

Conclusion

The clear comparison among methods that was hoped for in this study was only partially achieved because the three methods were not used to obtain the same values. And the results that could be compared were not expected to be similar because of different definitions and measurement techniques used. These differences complicated the comparison of value estimates derived from the various models by making it difficult to account for differences in value estimates on theoretical grounds.

Whereas all three methods can be shown to be derived from a constrained utility-maximization problem, the application of each requires data on different variables and optimally a different experimental design. For example, the successful application of the zonal travel-cost method was enhanced by an experimental design that ensured a large number of participants from many zones at a particular site, whereas the successful application of the hedonic travel-cost model required recreationists from a particular zone visiting a large number of sites at various distances from that origin. For both travel-cost and hedonic travel-cost methods, the cost of a trip was equal to the distance multiplied by some estimated cost of transportation per mile (which may or may not have included the time component of travel). The household-production method would have had improved results if independent data had been available on time taken to travel to the site and travel expenditures. It was useful, for the household-production method, to have data on several fishing sites visited by anglers from different distances.

The questionnaire for this study was designed with only the travel-cost model in mind, and many shortcomings were found when this data base was used to apply both the hedonic travel-cost and the household-production methods. Indeed, one major result of this work was finding that a significant amount of preplanning in questionnaire design is necessary if a single data base will be used to estimate values by more than one method.

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Three market-based methods for estimating values of sport fishing were compared by using a common data base. The three approaches were the travel-cost method, the hedonic travel-cost method, and the household-production method. A theoretical comparison of the resulting values showed that the results were not fully comparable in several ways. The comparison of empirical results showed differences in values not easily accounted for on theoretical grounds. The data base was not designed to provide data for all three methods, and some of the resulting models explain only a small proportion of the variation.

Keywords: Recreational value, fishing, models.

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